Three papers about China's recent economic reform and firms' productivity

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THREE PAPERS ABOUT CHINA'S RECENT ECONOMIC REFORM AND FIRMS' PRODUCTIVITY

by

HAOYU ZHOU

B.A., University of British Columbia, 2011
M.A., University of British Columbia, 2012

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Approved by

First Reader

Marc Rysman
Professor of Economics

Second Reader

Jordi Jaumandreu
Senior Academic Researcher

Third Reader

Hiroaki Kaido
Assistant Professor of Economics

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HAOYU ZHOU

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Major Professor: Marc Rysman
Professor of Economics

ABSTRACT

The first chapter of this dissertation argues that privatization and other policy changes in China during the past decade had a direct effect on input prices. This is in contrast to most previous work, which instead emphasized the effect of privatization on productivity. I illustrate the importance of taking such differences into account by estimating the parameters of a static firm competition model using the Chinese Industrial Enterprises Database and calculating a measure of total factor productivity for each firm out of those estimates. The results of my analysis indicate that the percentage difference in productivity between private and state-owned firms may be overestimated by as much as 135 percentage points if the difference in input prices is not properly addressed.

The second chapter of my dissertation establishes empirical support for such a difference in input prices by constructing a dynamic structural model of privatization, firm heterogeneity and industry evolution, and estimating its parameters using the Chinese Industrial Enterprises Database. My estimates of the model confirm many well documented institutional features about China's reform, including "grasp the large and let go of the small" policy, easy access to credit for state-owned enterprises

(SOEs), and selection for privatization according to firms' probabilities of success. In addition, the estimated structural model provides the basic tool for policy simulations and enables us to see the effects of hypothetical policies, for example "grasp the small and let go of the large" and "removing SOEs' easy access to credits".

In the last chapter, I study the effect of privatization of state-owned enterprises in China, focusing on not only the effect of privatization on a firm's productivity, but also its effect on market output allocation. I use the method proposed by Olley and Pakes (1996) to find improvements in average market productivities for all industries in China. This growth in productivity resulted from enterprises becoming more productive, but not from more efficient output allocation within the market. Private firms are proven to be more productive than state-owned enterprises in all industries, but privatization itself improved firm efficiency only for some industries.

Contents

List of Tables

List of Figures

List of Abbreviations

BBL	. . . .	Bajari, Benkard, and Levin (2007)
GMM	. . . .	Generalized Method of Moments
IID	. . . .	Independent and Identically Distributed
IMF	. . . .	International Monetary Fund
LP	. . . .	Levinsogn & Petrin (2003)
OLS	. . . .	Ordinary Least Squares
PPI	. . . .	Producer Price Index
SOE	. . . .	State-Own Enterprise
TFP	. . . .	Total Factor Productivity

Chapter 1

Governments' Favoritism toward State-Owned Enterprises and Firms' Productivity

1.1 Introduction

During the Second Sino-Japanese War and the Chinese Civil War from 1937 to 1949, China's economy was heavily disrupted. Afterward, the victorious communists installed a planned economic system strictly following the Soviet model, but were not able to bring about economic recovery. Furthermore, the famine accompanying the Great Leap Forward which killed between 30 and 40 million people, and the purges of the Cultural Revolution drove the economy deeper into a hole. Data showed that urban Chinese citizens had experienced virtually no increase in living standards since 1957, and that rural Chinese had no better living standards in the 1970s than the 1930s (Brandt and Rawski (2008)).

The economic turning point arrived when reformists in the Communist Party of China assumed power after Mao Zedong's death. In 1978, designed and guided by Deng Xiaoping, China started its economic reform and adopted the principle "Reform and Opening-up" which entailed twin policies of opening its door to foreign trade and investment, and reforming its state-owned enterprises (SOEs hereafter).[1] Since then, unprecedented economic growth occurred, with overall GDP increasing by a 9.5%

[1] The reform principle is called "Gai Ge Kai Fang" in Mandarin Chinese, and it is also translated by various sources as "Reform and Opening".

average annually from 1978 to 2014.[2] Today, China's socialist market economy is the world's second largest economy by nominal GDP, and the world's largest economy by purchasing power parity according to the International Monetary Fund (IMF).

China's massive and rapid economic transformation has attracted a great deal of attention, and much research has been devoted to China's economic reform policies in the past decade.[3] However, there are several shortcomings in the existing studies, that warrant more careful and thorough attention. First of all, most current researches focus on the effect of government ownership on total factor productivity and ignores the effect on input prices. In fact, SOEs are always favored by governments and granted easy access to loans from banks, most of which are also owned by governments.[4] In other words, SOEs are able to obtain investment at a cheaper price than their private counterparts. Second, even though there are papers focusing on the role played by input mis-allocation (which can be a result of different input prices) on industry productivity measure, for example Hsieh and Klenow (2009), they study the issue with a static model and overlooked the fact that input price affect firms behavior in a dynamic fashion. In addition, while Hsieh and Klenow (2009) view state ownership as a possible source of capital cost heterogeneity, they do not study the relationship between which firms are state owned and the behavior and productivity of those firms.[5] On the other hand, my approach is much more specific

[2]Many economists suspect that the accounting method used in China might over estimate the GDP growth rate by roughly two percentage points, but the growth rate is still impressive even without any measurement errors.

[3]Some of the most notable ones are Kroeber (2016), Naughton (2007), Starr (2001), Hu and Khan (1997), Lin (2011), Bai, Lu and Tao (2009), Brandt, Van Biesebroeck and Zhang (2012), Jaumandreu and Yin (2016), Rodrik (2006), Montinola, Qian and Weingast(1995), Yao (2002), etc.

[4]By using plural form 'governments', I am referring to all levels of government (national, provincial, municipal, etc.) in China that are involved in investment and privatization decisions.

[5]The issue is explicitly explained in Hsieh and Klenow (2009). "The static monopolistic competition model we deploy could be a poor approximation of all three countries. Although we provided reassuring evidence on these concerns, our investigation was very much a first pass. In addition to investigating these issues more fully, future work could try to relate differences in plant productivity to observable policy distortions much more than we have." (Hsieh and Klenow (2009))

on those issues.

To better understand the importance of different input prices, we consider a situation where firms decide how much capital to invest for the coming year according to their observed current productivities. If SOEs face a very low investment price, the relationship between investment level and productivity will be weakened, and SOEs are very likely to over-invest in capital relative to private firms with the same productivity level. Hence SOEs are inefficient because they operate at a lower marginal of product of capital, and their productivity measures can certainly be improved if they pay careful attention to how much to invest in capital. In contrast, I propose a different channel to explain productivity differences among different types of firms. I believe that the SOEs' inefficiency results from certain qualities of the firms that attract low-productivity labors, but has nothing to do with bad decisions concerning how much to invest due to low input cost.[6] In sum, I expect that the estimated productivity differences between these two types of firms may well be exaggerated in the previous works in which the difference in input prices is over looked.[7] Unfortunately, to the best of my knowledge, there is no previous work focusing on such an important issue or explicitly modeling firms' distinct behaviors under different input prices.

In this paper, I construct a simple model and estimate firms' revenue function as well as their productivities following Peters, Roberts, Vuong, and Fryges (2015). The model takes ownership as one of the state variable in order to control for input price difference and allow the productivity level to be different for different types of firms. In addition, this model differs from the previous work (Chen, Igamiz, Sawadax and Xiao(2017)) by allowing productivity to grow in different rate as well, which is

[6]This new channel of explaining the difference in productivities between SOEs and private firms will become clear once the theoretical model is introduced.

[7]Chen, Igamiz, Sawadax and Xiao(2017) have estimated that, overall, private firms in China are 229% more productive than their state-owned counterparts, but this is proven to be too big of a difference once input prices are incorporated.

accomplished by adding an ownership dummy variable into the productivity evolution function. This addition to the model is how I control for the fact that different types of firms have different incentive to improve their productivity due to distinct investment costs. Thereafter, the estimated model and productivity measures provide us an opportunity to compare firm productivity among groups of firms with different ownership.

The results prove my expectation that the productivity difference between private firms and SOEs are overestimated in previous papers, and our estimates are much more reasonable. First of all, the estimates confirm that not only private firms are more efficient than their state-owned counterparts, but they are also more likely to realize a higher productivity in the next period than an SOE with the same level of current productivity (i.e. their productivity grow faster than their state-owned counterparts). Second, if comparing the average productivity of private firms with that of SOEs, the former appears to be more efficient than latter by as large as 39.357%. Third, when comparing the productivity of privatized SOEs before privatization with that after, SOEs see 47.711% improvement in productivity once privatized. Finally, The SOEs selected for privatization have a higher average productivity than SOEs that do not go through the privatization process, which illustrates that governments are more likely to privatize more productive SOEs, but more likely to terminate less productive ones that may have a hard time to survive on their own once privatized.

In addition to investigating the importance of different input prices, the paper also contributes to the literature in the following aspects. First, this is the first paper that addresses the data misinterpretation problem resulting from the mass layoffs (i.e., the surge in layoffs) in the 1990s; ignoring this issue significantly biases measures of SOE productivity. Second, Even though it has become standard in the literature to assume that SOEs maximize profit during that period of time, previous papers did not provide convincing evidences. In this paper, I will offer formal justification to SOE profit maximizing behavior with the institutional features before privatization.

The structure of the paper is as follows. In section 1.2, I present background information about China's economic reforms that will help readers understand some of my modeling decisions in the later sections. In section 1.3, I provide a brief description of the data set and present relevant summary statistics. My theoretical model of firm competition is presented in Section 1.4 and the estimation method in Section 1.5. Section 1.6 summarizes the parameter estimates and explains their validity and implications. Section 1.7 concludes.

1.2 China's Economic Reforms

To study China's economic reform more carefully and take into account some institutional factors that have been neglected in the past, such as different input prices and mass layoffs, we must begin with background information about China's development in general. In this section, I briefly describe China's economic reforms since 1978, as well as some specific characteristics of China's market that will help readers understand my modeling choices in section 1.4.

1.2.1 Course of Reforms

The Chinese economic reform was started in December 1978 by reformists within the Communist Party of China, led by Deng Xiaoping.[8] The goal of the reforms was to establish a system known as "Socialism with Chinese Characteristics" and, generally speaking, "Chinese Characteristics" referred to market principles existing within a socialist system. Contrary to the Soviet Union's reform, China took a slow and gradual approach that was summarized by Deng as "cross[ing] the river by feeling

[8]Deng Xiaoping is regarded by the Chinese people as the architect of the Chinese economic reforms.

the stones," meaning that even though China was moving forward in new directions, it needed to stay grounded, to proceed incrementally, feeling its way forward even amidst uncertainty. Today, the reforms have persisted for almost 40 years and are still changing China on a daily basis.

In general, we can summarize the reforms by identifying the following four stages. In the first stage of the reform (1978-1984), Deng and his reformist allies concentrated on agriculture, a sector long neglected by the Communist Party. They implemented a central reform theme of decollectivizing agriculture and emphasizing the household-responsibility system, which divided the land of people's communes into private plots. Henceforth, farmers were given the right to keep parts of their lands' output while paying a share to the state. This movement effectively boosted incentives, which increased production in the agricultural sector as well as the living standards of hundreds of millions of farmers.[9] In urban industry, a dual-price system was introduced, under which SOEs were for the first time allowed to sell any production above the plan quota in a free market at a negotiated price.[10] These initial changes in China's economic system allowed citizens to reverse the shortages of the Maoist era to some extent. During the 1980s, the adoption of the Industrial Responsibility System, allowing the use of contracts by individuals or groups to manage enterprises, further promoted the development of SOEs. Furthermore, for the very first time since the foundation of the People's Republic of China in 1949, private businesses were allowed to operate and to compete with SOEs, and they gradually began to account for a greater percentage of industrial output. At the same time, a series of special eco-

[9]China's path to reform is often referred to as a bottom-up approach, because it started with the most fundamental sector of the economy, agriculture, and then built reforms in other industries on top of a successfully transformed agricultural system. This is actually the opposite of *perestroika* in the former Soviet Union, which adopted a top-down approach that indirectly resulted in its disintegration. The bottom-up approach is considered by economists as an important factor contributing to the success of China's economic transition.

[10]Before the reform, SOEs produced according to government plans and sold all outputs back to the government at predetermined plan prices.

nomic zones for foreign investments were created, as the country was finally opened to foreign investment for the first time since 1949.

During the second stage of the reform (1984-1993), the initial reforms in the first stage continued, and regulations on private ownership and government interventions were lifted further. A notable contribution in this stage was the decentralization of state control, which left many production decisions that formerly made by the central government to local provincial governments and enabled local governments to experiment and find their own ways of increasing economic growth. Among numerous experiments, firms that were nominally owned by local governments but effectively privately-owned, for example township and village enterprises, began to gain market share at the expense of the state sector. It should be noted that, even though there was some small-scale privatization of SOEs that eventually had become unsustainable, large-scale privatization was not the focus of the reforms until 1992. Although the economy grew quickly during this period, it was not in satisfactory condition as the inefficient state sector continued to grow, heavy losses in some SOEs drained the economy, and inflation became problematic.

The third stage (1993-2005) saw a series of radical transformations in the economy. Despite Deng's death in 1997, reforms were able to continue as his successors, Jiang Zemin and Zhu Rongji, were also ardent reformers. In 1997 and 1998, large-scale privatization was officially started under the guise of the "grasp the large and let go of the small" policy. This policy was adopted in September 1997 at the 15th Communist Party Congress. The "grasp the large" component indicated that policy makers should maintain state control over the largest state-owned enterprises, while "let go of the small" meant that governments should relinquish control over smaller state-owned enterprises. In the following several years, all state enterprises, except a few large monopolies, were liquidated and their assets sold to private investors.

Progress was so far reaching that as much as 48% of SOEs in 2001 were reformed by 2004 (Brandt and Rawski (2008)). The domestic private sector first exceeded 50% of GDP in 2005 and expanded further thereafter. Many other initiatives were launched by governments during the same period, including tariff reduction, regulation alleviation, trade barrier removal, banking system reform, the dismantling of the Mao-era social welfare system, investment cuts in military-run businesses, inflation reduction, and participation in the World Trade Organization (WTO). These moves were accompanied by the formation of large discontented groups, mostly consisting of laid-off employees of SOEs during the reforms (a phenomenon known as mass layoffs in the 1990s or "Xiagang" in Mandarin Chinese).

The pace of reform was significantly slower during the very last stage (2005 to the present). In fact, the Hu-Wen Administration was so conservative that some of Deng's achievements in economic reforms were reversed in 2005. Governments increased subsidies and applied more controls over the health care sector. The privatization process also was halted. In addition, they increased investment in the privileged state sectors, which on the other hand created national giants capable of competing with foreign corporations.

1.2.2 Credit Market

It is well documented that SOEs in China receive easy access to credits from state-owned Chinese banks (Boyreau-Debray and Wei (2005)), while private firms face significant financial constraints (Allen, Qian, and Qian (2005)), especially for capital goods purchases (Dollar and Wei (2007); Riedel, Jin, and Gao (2007)). The reasons behind such preferential treatment of SOEs can be explained from two different perspectives. First, a major source of government revenue in 1990s was profits made by SOEs, and therefore the profitability of SOEs was a major concern of governments. Second, loans to SOEs are considered less risky because they are usually backed by governments when these enterprises experience financial difficulties. Thus it is not surprising that governments tend to allocate capital systematically away from the private sector and towards SOEs, even though the latter are less productive. This further leads to an inefficient allocation of capital by the Chinese financial system (Boyreau-Debray and Wei (2005)).

In addition, state-owned banks dominate China's financial market. The banking system in China comprises the central bank, four large state-owned commercial banks, three policy banks, 10 national joint-stock commercial banks, about 90 regional commercial banks, and thousands of urban and rural credit cooperatives. Yet, as of late 2001, the four state-owned commercial banks accounted for 63% of loans outstanding and 62% of deposits. With 103,000 branches among them, they are the only financial institutions that cover virtually all locations in China.

Summarizing the information presented above, we know that it is easier for SOEs to obtain loans from state-owned banks, and most loans are initiated by state-owned commercial banks. In other words, SOEs on average should have received better prices for loans, in terms of lower annual interests rates, than private firms. In my theoretical model below, I distinguish the unit costs of physical capital investment for state-owned and private firms, and expect my estimates to confirm this observation.

1.2.3 Grasp the Large, Let Go of the Small

At the 15th Communist Party Congress in September 1997, a series of policies generally summarized as "grasp the large, let go of the small" was formally adopted. As noted above, the "grasp the large" component indicates that policy makers should focus on maintaining state control over the largest state-owned enterprises, whereas "let go of the small" refers to a policy that small state-owned firms were to be relinquished. Relinquishing control over these enterprises took a variety of forms, including privatization and termination. [11]

Instead of adopting a uniform reform policy for both large and small SOEs, the governments decided to take conservative and gradual steps and experiment with policy on the smallest SOEs first before applying it to larger ones. According to policy makers, this is a good approach because it slows the pace of transformation and prevents political turmoil. Additionally, delaying policy reforms for larger enterprises enabled them to pursue another objective, that of creating capable national giants in order to compete with other leading corporations in each industry at the global level.

In fact, “grasp the large” was much more complicated than “let go of the small,” which only involved privatization or termination of selected SOEs. There were two major approaches to “grasping” large SOEs, one involving a change in legal registration and one without. The latter was the most strict approach, which was to maintain public ownership of an SOE as it was, without any restructuring or new registration. In contrast, many state-owned firms were merged into large industrial conglomerates, and the control over these conglomerates was to be consolidated by the central government or by local governments.[12] In this case, SOEs were often incorporated as limited liability corporations, some of which were even publicly traded, but the dominant share holders were state-owned conglomerates. As a result, this complication makes it difficult for us to identify state ownership using only registration status, and I will discuss in detail how I define state ownership in section 1.3.

1.2.4 Road to Privatization

Large-scale privatization was officially started in 1997 and 1998, when China's SOE reform had been in progress for almost 20 years. Yet the firms in 1997 were nothing like the ones before 1979. It is thus important for us to understand how

[11] Hsieh and Song (2015) present a comprehensive set of empirical facts illustrating the processes of the reform using the same dataset as mine.

[12] Hsieh and Song (2015) show examples of this in China's steel sector and automobile industry.

reforms had changed China's economy before privatization, in order to model firms' behaviors accurately. In this subsection, I briefly review some important policies prior to privatization that help to explain some related modeling choices in section 1.4.

The first few years of the reform were designated as the "period of readjustment" (1979-1983), during which key imbalances in the economy were to be corrected and a foundation was to be laid for a well-planned modernization drive. The main policies in this period were to increase the autonomy of enterprise managers, reduce the emphasis on planned quotas, allow enterprises to produce goods outside the plan for sale on the market, and permit enterprises to experiment with the use of bonuses to reward higher productivity. All these actions increased the incentive for enterprises to make profits and substantially added to their autonomy.

From 1983 to 1986, the government implemented "Tax Replacing Profit, Loan Replacing Funding." The goal was to re-balance profit shares between SOEs and the state by means of a modern taxation system. Rather than remitting all of their profits to the state, as was normally done, these enterprises were allowed to retain a balance, from paying a tax on their profits, for reinvestment and distribution to workers as bonuses. In addition, instead of obtaining investment funds directly from governments, SOEs had to apply for loans at government banks and were obligated to pay interest even though many bank loans carried no interest and did not have to be repaid. As of 1987 the interest rate charged on such loans was still too low to serve as a check on unproductive investments, but the mechanism was in place. This is also the origin of SOEs' easy access to credits discussed above.

Since 1986, the central government implemented a series of policies to isolate management rights from property rights and to strengthen the autonomy of enterprise managers. The most notable was "the system under which the factory director assumes full responsibility," which endowed the factory director with the ultimate right to make production decisions for the firm. In fact, the official managers included not only the factory director but also a enterprise management committee formed by heads of different departments, chief engineer, chief accountant, secretary of the party committee, chairman of the union, shop stewards and so on. The enterprise management committee was given the obligation to advise and supervise decision-making. However, in the event of a conflict between the factory director and the enterprise management committee, the factory director could make the final decision against others' opposition. It is important to note that, under this system, the secretary of the party committee became a member of the enterprise management committee and was no longer the decision-maker of the SOE. Thus governments that were the owners of SOEs reduced their role in business management.

In addition to large-scale privatization, the 15th Communist Party Congress in 1997 also announced "hard budget constraints" for all SOEs. This meant that the role of governments in decision-making was to be eliminated, as well as their role in providing financial support. Many SOEs were merged, sold, or terminated, and the surviving ones were on their own when dealing with their debt, investment, and profits. They also exercised full autonomy in hiring and firing, and mass layoffs ensued as SOEs sought to release redundant labor and cut financial losses. Additionally, the performance of SOE directors was evaluated solely by their ability to make a profit, rather than to fulfill social functions previously forced on SOEs by governments.

Thus, SOEs in the starting year of my sample (1997) were nothing like those in 1979. During almost 20 years of reform, a cluster of policies promoting greater flexibility, autonomy, and market involvement made significantly more opportunities available to most enterprises, generated high rates of growth, and improved market efficiency. Enterprise managers gradually gained greater control over their units, including the right to hire and fire, although the process had required endless struggles with bureaucrats and party cadres. All of these changes over the years are very important to my modeling considerations. Firms' behaviors and decision-making processes are greatly affected by the economic system, which I will discuss in detail when explaining my theoretical model in section 1.4.

1.2.5 Mass Layoffs in the 1990s

In the 1990s, as a byproduct of the reform, the number of laid-off employees exploded. Many studies have shown that SOEs suffered from a serious over staffing problem that contributed to their low productivity. However, as more and more SOEs started to adopt "the system under which the factory director assumes full responsibility," governments no longer played a dominant role in those enterprises and were not more responsible for compensating their losses. Therefore, in order to survive intense market competition, often the very first thing the managers of SOEs decided was to lay off redundant labor, a process also referred to as "mass layoffs in the 1990s." In this subsection, I describe how China's labor market changed over time and why understanding the "mass layoffs" is important for my study.

Before 1980 urban workers in China benefited from the so-called "iron rice bowl." Typically, workers were assigned jobs by state authorities and employment was often guaranteed for life. SOEs were intended not only to provide jobs but to serve as health and welfare agencies for urban Chinese workers. Housing, health insurance, pensions, childcare, and, in some cases, education for children were arranged by SOEs, and wages were more or less guaranteed. SOEs in this era were designed to be a major source of economic security for Chinese workers, and their productivity and profitability were of secondary importance.

In the mid-1980s, many SOEs started to transform their leadership systems to meet the standard of "the system under which the factory director assumes full responsibility." The most notable difference of this new system from the previous planned economy system was that SOEs were mainly concerned with their own profits instead of governments' social targets when making decisions. This was a big step toward a market economy even though there were few privatizations or ownership changes. During this period of time, SOEs were still not fully autonomous in hiring and firing their employees, but the power given to the managers became a stepping stone toward mass layoffs later.

In the early 1990s, the private sector had developed at a very fast pace while SOEs had experienced high debt ratios, large numbers of redundant laborers, heavy social responsibilities, low incentives, and, most importantly, financial losses. The first half of 1996 saw 43.3% of SOEs losing money, and almost all SOEs reported losses in the first quarter of 1998 (Price and Fang (2002)). Among all the problems faced by SOEs, the most acute was that SOEs were desperate to dump their redundant labor but had limited rights to do so because of their social responsibilities enforced by governments. In addition, governments' budgets were too tight to provide any subsidies, which were also not allowed under the new system. Nevertheless, SOEs started to experiment with some creative alternatives in order to survive, and were able to cut their labor force without any official firings. More specifically, many employees of SOEs were asked to stay at home without any tasks and paid only 20% to 30% of their regular wage. In this way, the laid-off workers were still registered officially as employees, but were laid off in reality.

The Fifteenth National Congress in 1997 was a watershed event, which completely changed the existing arrangements. After 1997 all SOEs faced "hard budget constraints." With much more restricted budget and greater autonomy, some enterprises began to initiate bankruptcy, restructuring, or mergers. Hence it became critical for them to reduce their workforce as quickly and massively as possible, and more and more workers began to be placed off-duty. In the context of this massive workforce reduction, most workers retained a contractual relationship with SOEs and a few even continued to receive some of their previous benefits (e.g., housing, health insurance, child care, etc.), albeit in significantly reduced amount in most cases. However, they were neither paid a wage by SOEs nor officially registered as employees.

As described above, the changes to China's labor market during the reforms were very complicated. It turns out that the number of employees reported in the data for certain years may be mistakenly interpreted if we ignore the details involving mass layoffs. In section 1.3.2, I discuss in great detail the potential risk of misunderstanding the data and present my simple and effective method of dealing with it.

1.3 Data Set and Summary Statistics

This section describes the data set and presents relevant summary statistics. It shows how I process the raw data into a set of data entries that is suitable for use in this study. Additionally, I carry out several reduced-form regressions in order to find empirical evidence supporting the institutional factors underlying China's reforms and my modeling choices.

The data set used to estimate my model is a subset of the Chinese Industrial Enterprises Database, which consists of an unbalanced panel data set extracted and reorganized from the annual surveys of manufacturing and mining firms conducted by the National Bureau of Statistics of China. The target firms of the survey include all state-owned enterprises and sizable non-state-owned enterprises with annual sales revenues larger than 5 million RMB (approximately 724,000 US dollars).[13] Up to 2007, there are more than 330,000 enterprises recorded, and their total gross industry output value accounts for around 95% of the national total. The recorded enterprises span more than 40 different industries and every enterprise has hundreds of variables.

[13] In this paper, I use the RMB:USD exchange rate for March 8, 2017.

All of the above make this database the most comprehensive and authoritative firm-level database, and hence the most important resource in studies of economics and management in China.

My data set encompasses the period from 1997 to 2006, which mainly correspond to the third stage of the transition introduced in section 1.2.1.[14] Since the third stage was mainly about large-scale privatization, these data are perfect for studying firms' ownership changes and their effects on the economy. Among the large variety of events occurring during this period, in addition to SOEs' easy access to loans, the most relevant to my study include the "grasp the large and let go of the small" policy as well as the SOE reforms prior to privatization and mass layoffs, on which I have devoted much discussion in sections 1.2.3, 1.2.4, and 1.2.5, respectively.[15] Later in this section, I provide further supporting empirical evidence, and explain a bit more about why we must pay attention to those events and how neglecting them affects my results.

Even though there are a wide variety of industrial firms in the survey, I focus on the Electronic and Telecommunications Industry (having the two-digit industry code 40 in the Chinese Industrial Enterprises Database) in this paper. The first reason I select this industry is that it is one of industries most strongly influenced by the reforms. Bai, Lu and Tao (2009) list the percentages of privatization for all industries reported in the Chinese Industrial Enterprises Database, and the Electronic and Telecommunications Industry, with a percentage of privatization of 26.6%, is among

[14] Even though I also have survey data for 2007, the lack of firm IDs makes it difficult to match the 2007 data with the firm entries in the previous years. Despite this obstacle, I was able to carry out my estimation and obtain meaningful results without the entries for 2007.

[15] All other policies implemented in this stage are not as relevant. Many of them, for example tariff reduction, trade barrier removal, and joining WTO, concern imports and exports which are not the main focus of my model. Many other policies have nothing to do with the market I am working on, such as the dismantling of the Mao-era social welfare system. Finally, some policies have no supporting data, for example regulation alleviation and investment cuts in military-run businesses.

the 10 most highly privatized industries.[16] The higher privatization rate assists us in discerning the effects of the relevant policies. Second, the Electronic and Telecommunications Industry is much less regulated and monitored by governments compared to industries such as Medical and Pharmaceutical Products, Raw Chemical Materials and Chemical Products, Metal Mining and Dressing, Petroleum Refining and Coking, and so on. The minimal role of governments at all levels makes it easier to isolate the effects of other policies from those of privatization, which further reduces complexity when interpreting model estimates. Third, it is one of the industries dominated by private firms during the sample period. In 1997, the beginning of my sample period, only 26.374% of firms are SOEs in this industry, which is one of the industries with the lowest share of public firms in that year, compared to many other industries including Coal Mining and Processing (51.172% SOEs), Petroleum and Natural Gas Extraction (95.238% SOEs), Food Production (47.185% SOEs), Tobacco Processing (90.857% SOEs), etc. Hence the Electronic and Telecommunications Industry functions in a way that resembles a market economy more closely during my sample period, whereas the other industries mentioned above are embedded with more characteristics of a planned economy. To summarize, I am able to avoid many complications created by a highly concentrated and overly controlled environment when working with this industry.

The variables used for this study include legal person number (unique firm identification number), two-digit industry identification number, location identification number, main operation revenue and cost, annual average number of employees, fixed assets, long term investment, and, of course, ownership and registration type. I use these variables to construct measures of revenue, cost, labor, real capital, ownership, and so forth. All value-based variables are discounted using the producer price index

[16]The highest percentage of privatization is 37.8%, for the Medical and Pharmaceutical Products Industry.

(PPI) found in China's statistical year-book.

I use firms' legal person number provided in the data to match firms over time. Unfortunately, as discussed in section 1.2.3, the number may change when a firm is restructured or acquired by another firm, and when this happens I lose track of the firm. Therefore, for the sample of firms that I cannot match over time using the legal person number, I follow Brandt, Van Biesebroeck, and Zhang (2012) and use firms' names, addresses, and phone numbers to identify surviving firms.

I focus on firms' actual production and use main operation revenue and cost, instead of total revenue and cost, to measure their revenue and variable cost, respectively. Main operation revenue and cost are appropriate measures to use because they only contain the incomes and expenditures related to primary production, but exclude those from other activities, for example land appreciation, investment dividends, bank interest, employees' holiday dividends, crisis management costs, etc., which do not correctly reflect information about the firms' production process, nor about their true productivities.

Fixed assets reported in the data is the accumulation of acquired assets at their original purchase prices. Hence, taking fixed assets as a measure of real capital directly without any adjustment would be problematic. To address this issue, I follow the approach proposed by Brandt, Van Biesebroeck and Zhang (2012), in which they develop a procedure based on a perpetual inventory method that converts capital values at original purchase prices into real values that are comparable across time and firms. The detailed procedure can be found in the appendix of this paper.

As mentioned in section 1.2.3, an SOE may be reincorporated but still predominantly owned by state-owned conglomerates. Therefore, using firms' legal registration type to identify state ownership may cause a problem because a firm registered as a limited-liability corporation, shareholding firm, or foreign firm can ultimately be state controlled and behave just like a public firm.[17] Even though this problem is not as pronounced in the Electronic and Telecommunications Industry as in many other heavily regulated industries such as Petroleum and Natural Gas Extraction, Ferrous Metal Mining and Dressing, and Medical and Pharmaceutical Products, I have decided to minimize the error to the extent possible and follow Hsieh and Song (2015) in defining a firm as state-owned when its share of registered capital held directly by the state exceeds or equals 50% or when the state is reported as its controlling shareholder.[18] This definition excludes firms in which the state holds a minority share through a holding company.

1.3.1 Summary Statistics

Table 1.1 provides some basic summary statistics of my firm-level panel data for the Electronic and Telecommunications Industry. The mean level of all variables as well as their standard errors are calculated for each sample year. All values are in millions of RMB, except for the number of workers and the number of firms. On average, all variables rise gradually over time, corresponding to China's fast-growing economy and the growth of enterprises during those years. Because of both the growing economy and the policies encouraging new private entrants, the number of firms in the industry grows by more than three times, from 1983 firms in 1998 to 6297 firms in 2007. Over all sample years, there are 43,710 observations in total, with main operation revenue of 289.476 million RMBand cost of 269.704 million RMB, implying a profit margin of 7.33%. An average firm is endowed with 65.778 million

[17] At the first glance, it may seem improbable that a foreign firm could in fact be state-owned. However, this can happen because a firm of which at least a third of the ownership is foreign held can be registered as a foreign firm. Therefore, it is possible that as much as 66.6% of a "foreign firm" can be owned by various levels of government in China. The joint ventures of the Shanghai local government with GM and Volkswagen (Shanghai-GM and Shanghai-Volkswagen) are examples of this situation.

[18] Please consult Hsieh and Song (2015) for a detailed explanation of the definition of state ownership.

RMB worth of real capital and hires 519.009 employees.

For this study in particular, it is also very important to disaggregate firms according to ownership type. Table 1.2 shows that the percentage of SOEs decreases from 26.374% in 1998 to only 3.637% in 2007. This drop in the percentage of SOEs is the result of both the "SOE reform" which caused the number of SOEs in the market to drop from 523 to 229 in 10 years, and the "opening-up" which added thousands of new private entrants to the economy. By the end of the sample period, the percentage of SOEs (3.637%) is so low that the industry is unlikely to be endowed with any characteristics of a planned economy.

1.3.2 Evidences of Mass Layoffs

To make certain the data represent market correctly, it would be helpful if we could find empirical evidence that justifies the observations about layoffs presented in section 1.2. In this subsection, I focus on finding evidence for mass layoffs in the 1990s, and related issues.

Let's first take a look at some examples, and try to understand exactly how mass layoffs were carried out. Through inspection, I find out that there are two basic types of laying-off processes. An example of the first type is Kai Feng Guang Xia Electronics Production Ltd., in which there is only a one-time mass layoff, as shown in the left panel of Figure 1·1. In contrast, Wuhan Zhongyuan Electronics Group Co. represents the second type, where two mass layoffs occur back to back in successive years, as in the left panel of Figure 1·2. These two types of mass layoffs cover almost all possible cases. To document this, I counted how many SOEs underwent a mass layoff only once, how many shed workers in two consecutive years, etc., and the results for different levels of worker declines are presented in Table 1.4. If we believe a mass layoff takes place when a firm gets rid of more than 30% of its current workforce, 229, 33, and 2 SOEs have experienced one, two, and three consecutive mass layoffs, respectively. One additional information shown by this result is that laying-off was unlikely to be a controlled process. In other words, I believe there was no adjustment cost entailed in employment changes, and the reasons are as follows. Firstly, there are very few firms that went through more than one mass layoff even when I define the layoff size to be as low as 30%.[19] Second, there are more than 100 firms (more than 14% of all SOEs) that have fired at least 50% of their employees within one year, which is too big of a drop to justify the existence of adjustment costs.[20] Third, there is almost no SOE that has experienced more than two consecutive mass layoffs.[21]

Now, I run some simple regressions to justify the existence of mass layoffs in the data. The hypothesis is that SOEs were finally free to shed their redundant labors without any limitations or legal consequences imposed by governments once "hard budget constraints" were in place after 1997. In other words, we should be able to see in the data large declines in the number of SOE employees if there was indeed a massive surge in layoffs. To do this, I classify all observations into three different groups, (1) private firms that are still private during the next year, (2) SOEs that become private during the next year (privatization), and (3) SOEs that are still state-owned during the next year, and define $D2$ and $D3$ to be dummies indicating observations in group 2 and 3, respectively. Then I regress the yearly changes in the number of employees on $D2$ and $D3$ along with other control variables. Table 1.3 reports the results of such regressions. I include only $D2$, $D3$, and a constant as regressors in Model 1, which in other words calculates the simple averages of labor differences from the current period to the next for the three groups. Private firms on average hired 64.012 employees each year while SOEs hired 16.642 if privatized (much

[19] If a labor adjustment cost is in fact in place, we should see SOEs shedding workers slowly and gradually to spread these costs over several years.

[20] If there were labor adjustment costs, SOEs would not try to shed this many of employees in a single event.

[21] Again, this proves that SOEs do not have an incentive to carry out layoffs gradually, as they would when adjustment costs are present.

less than private firms) and laid off 32.433 if there was no ownership change.[22] If I further control for the number of employees, real capital (firm size), and total wage bill in Model 2, similar results hold. For firms with the same level of hiring, size, and cost, labor changes in SOEs are 53.797 and 111.232 less than in private firms in the cases of privatization and no privatization, respectively. The regression results provide some preliminary evidence that SOEs were indeed able to shed unwanted workers and mass layoffs did occur.

Based on the empirical evidence above, it appears that my understanding about mass layoffs and the labor market is fairly accurate. However, there is one additional concern, that the reported number of employees may be overstated for the observations proceeding a mass layoff. Specifically, the mass layoff itself is not a concern, but I worry about the case in which some workers might be officially registered as employees, but actually stayed at home with no job. Recall the second example presented above, of the Wuhan Zhongyuan Electronics Group Co. where the pace of layoffs may seem too fast to be true, since more than 70% of their workers went jobless in less than two years. In fact, the discussion in section 1.2.5 suggests that such dramatic changes in numbers may not reflect real layoffs. Prior to "hard budget constraints," many SOEs had to shed redundant employees even though they were not de jure to do so and had to keep those employees registered at all times. Once the "hard budget constraints" were implemented in 1997, SOEs were given the right to fire and could finally wipe those jobless employees off the list.[23] Therefore, such dramatic changes

[22] I am not surprised to see a positive labor change in group 2, because it is possible that SOEs shed so many employees prior to privatization that they actually experienced a lack of labor once becoming more efficient after privatization. If we take a look at all industries, 33 out of 39 exhibited negative labor changes in group 2 and 34 out of 39 showed negative changes in group 3, which confirms the observations regarding nationwide mass layoffs.

[23] In some SOEs, massive layoffs occurred one or two years after 1997. This is not unreasonable because (1) it took some time for local governments to react to the new policy designed by the central government, and (2) the SOEs also may have needed time to figure out how to implement the layoff.

may simply involve getting rid of names from the employee registration list, instead of real layoffs. To show this is in fact the case, I plot in the right panels of Figure 1·1 and 1·2 the revenue over time for the two example firms. Interestingly, their revenue did not drop in the years when mass layoffs took place. It is very unlikely that revenue kept increasing when large amount of worker were laid off. Therefore, the data could well overstate the true number of employees prior to mass layoffs and the measure of their labor productivity can be greatly impaired. Hence, I try to identify these cases and eliminate the observations that possibly suffer from this problem. Unfortunately, the existing literature is not able to take this factor into account and usually underestimates SOE productivities. Table 1.5 shows the labor productivities (measured by added value per worker) before and after deleting observations prior to mass layoffs for a variety of decline sizes. If a 30% annual drop in labor is defined as a mass layoff, there are 334 observations prior to layoff, of a total of 3259 state-owned observations. Dropping these cases from my data set increases average labor productivity by 3.911%, from 63,639 to 66,128 RMB added value per worker. In this study, I define a mass layoff to be a 30% drop in the labor force, and delete the observations prior to a mass layoff for a more accurate estimation.[24]

1.4 Theoretical Model

This section develops a theoretical model of firm competition in the production market. An incumbent firm i's short-run marginal cost at time t is given by

$$c_{it} = \beta_0 + \beta_a a_{it} + \beta_k k_{it} + \beta_w W_t - TFP_{it} \tag{1.1}$$

[24] There is no solid definition that tells us how big of a drop in the number of workers constitutes a mass layoff. I choose 30% because it appears to be fairly reasonable according to the results in Table 1.4.

where c_{it} is the log marginal cost, a_{it} is the age, k_{it} is the log real capital stock, and W_t is a vector of logged variable input prices that are common among all incumbent firms in period t.[25] A firm's capital stock is treated as a fixed factor in the short run, which affects its marginal cost in the sense that firms with large capitalization are more capable of transferring labor productivity into output, which in turn reduces their marginal costs. The firm-specific total factor productivity TFP_{it} captures differences in technology or managerial ability and is known by the firm but not observable to econometricians.[26] TFP may reflect many different sources of firm heterogeneity in principle, but I consider TFP primarily as a reflection of management quality, in the spirit of Bloom, Sadun, and Van Reenen's (2016) notion of "management as a technology." In this paper, I explicitly model TFP to depend on whether the firm is state-owned or private, since there is sufficient evidence suggesting that management quality varies significantly across firms with different ownership types, such that

$$TFP_{it} = \omega_{it} - \beta_\rho \rho_{it}, \tag{1.2}$$

where ρ_{it} is the private ownership dummy, β_ρ is its coefficient, and ω_{it} is the unobserved, structural productivity component that evolves over time. [27]

To sum up, cost heterogeneity across firms is caused by differences in the following three factors: capital stock, ownership, and the unobserved structural productivity component. This specification of the marginal cost function follows directly from Peters, Roberts, Vuong, and Fryges (2015). The key to this assumption is that marginal cost does not depend on the level of total output a firm produces. As

[25] I present one possible model in the appendix that can be used to derive a marginal cost like the one in equation (1.1). If the base of the model is same as the one presented in the appendix, W_t includes log prices of all variable inputs, in specific log wage rate and log price of intermediate input.

[26] The main reason for the negative sign in front of TFP is that equation (1.1) is a marginal cost function, and the more productive a firm is, the less cost it incurs.

[27] The dependency of TFP on ownership type strictly follows Chen, Igamiz, Sawada, and Xiao (2017)

shall be seen in a moment, the independence between marginal cost and total output simplifies the optimal pricing function, provides a tractable relationship between price and revenue, and in addition assists in the model's identification.[28]

Assuming incumbent firms operate in a monopolistically competitive market in which each firm produces a similar but differentiated product, and firm i faces the following demand function at time t,

$$Q_{it} = Q_t(\frac{P_{it}}{P_t})^{\eta} = \frac{I_t}{P_t}(\frac{P_{it}}{P_t})^{\eta}, \tag{1.3}$$

where

$$\begin{aligned} Q_t &= \left[\sum_{j=1}^{N_t} Q_{jt}^{\frac{1+\eta}{\eta}}\right]^{\frac{\eta}{1+\eta}} \\ P_t &= \left[\sum_{j=1}^{N_t} P_{jt}^{1+\eta}\right]^{\frac{1}{1+\eta}} \end{aligned} \tag{1.4}$$

are the aggregate industry output and the industry price index in period t. The firm-specific variables are its output level Q_{it} and sale price P_{it}.[29] Accordingly, I_t is defined as the market size at time t. Parameter η represents the elasticity of demand which captures the elasticity of substitution between different products. η is a negative number and assumed to be constant for all firms in the industry.

This demand function is adopted directly from the widely used monopolistic competition model by Dixit and Stiglitz (1977). However, unlike the traditional monopolistic competition model, we have a limited number of firms in the industry. To deal with this issue, I learn from Xu (2008) and follow a version of monopolistic competition by Yang and Heijdra (1993) where each firm's output decision influences the

[28] A marginal cost function independent of output can be derived from a firm's cost minimization behavior with some necessary assumptions. The model in the appendix provides such an example.

[29] With a bit of abuse in the choice of notations, I use Q and P with only a time subscript to represent the market-level quantity and price in a certain year, and I use Q and P with both firm and time subscripts for firm-level quantity and price at a certain time.

aggregate industry price index, which in turn affects firms' profits. In other words, one firm's production decision affects the profits of all other firms indirectly through the market price index.

I assume that the main objective of SOE is to make a profit, and thus model them as profit maximizers. However, one might question whether this assumption is reasonable, since SOEs were instruments of governments and performed social functions in a planned economic system. However, as described in section 1.2.4, two decades of market reforms greatly transformed China's economic system, as well as the role played by SOEs. Even though SOEs in 1997 might not have functioned in exactly the same way as private firms, their autonomy, flexibility, and the right to control their units made sure that they behaved very much like profit maximizers. Furthermore, as noted in Chen, Igamiz, Sawadax, and Xiao (2017), the governments' public finances have historically relied heavily on SOE profits, and their managers' (i.e., party and government officials') political careers mainly have depended on the firms' performance, which implies that managers of SOEs have the incentive to make as much profit as possible. Although I believe that non-profit objectives in SOEs still exist, these are insignificant compared to the goal of maximizing profit. In addition, non-profit objectives can take a great variety of forms and are difficult to specify because no systematic record of them exists. Consequently, a reasonable way to model SOEs is to consider those non-profit goals as idiosyncratic shocks to the main objective, maximizing profit.[30]

Thus, in each period, a firm maximizes its short-run profit by setting its price to

[30]Liu (2017) uses a similar argument to justify firms' profit maximizing behavior. Also, many other papers make similar assumptions including Jaumandreu and Yin (2014), Kalouptsidi (2014), and Chen, Igamiz, Sawadax, and Xiao (2017). To the best of my knowledge, this paper is the first to offer a comprehensive and detailed justification based on the history and institutional evidence of China's privatization.

be a constant markup over its marginal cost,[31]

$$P_{it} = \left(\frac{\eta}{1+\eta}\right) exp(c_{it}). \tag{1.5}$$

Given this optimal pricing function (equation (1.5)), together with log marginal cost (equation (1.1) and equation (1.2)), demand (equation (1.3)), and price index (equation (1.4)), the firm's log revenue $r_{it} = p_{it} + q_{it}$ can be derived, where I use lower-case p and q to denote log price and log quantity,

$$\begin{aligned} r_{it} = {} & log(I_t) + (1+\eta)\left[\beta_a a_{it} + \beta_k k_{it} + \beta_\rho \rho_{it} - \omega_{it}\right] \\ & - log \sum_{j=1}^{N_t} exp\left((1+\eta)\left[\beta_a a_{jt} + \beta_k k_{jt} + \beta_\rho \rho_{jt} - \omega_{jt}\right]\right). \end{aligned} \tag{1.6}$$

Given this simple form of pricing, I can also derive a succinct relationship between firms' short-run profits and their revenues,[32]

$$\bar{\pi}_{it} = \bar{\pi}_i(S_t) = \bar{\pi}(\omega_{it}, a_{it}, k_{it}, \rho_{it}, S_{-it}) = -\frac{1}{\eta} exp(r_{it}), \tag{1.7}$$

where $\bar{\pi}_{it}$, $\bar{\pi}_i(S_t)$, and $\bar{\pi}(\omega_{it}, a_{it}, k_{it}, \rho_{it}, S_{-it})$ are no more than different notations for the same profit value. I can substitute the revenue function (equation (1.6)) and find firms' profits given their own states and the state of the whole market,

$$\begin{aligned} \bar{\pi}_{it} = {} & \bar{\pi}_i(S_t) = \bar{\pi}(\omega_{it}, a_{it}, k_{it}, \rho_{it}, S_{-it}) \\ & = -\frac{I_t}{\eta \cdot PI_t} \cdot exp\left((1+\eta)\left[\beta_a a_{it} + \beta_k k_{it} + \beta_\rho \rho_{it} - \omega_{it}\right]\right) \end{aligned} \tag{1.8}$$

where

$$PI_t = \sum_{j=1}^{N_t} exp\left((1+\eta)\left[\beta_a a_{it} + \beta_k k_{jt} + \beta_\rho \rho_{jt} - \omega_{jt}\right]\right) \tag{1.9}$$

[31] The detailed derivation of the optimal pricing function is presented in the appendix.

[32] The derivation of this relationship between profit and revenue can be found in the appendix.

which I call the price index.[33] An interesting fact about this profit function is that, even though profit depends on the states of all other firms in the market (S_{-it}), we do not have to know more than the price index PI_t about it. This is actually an advantage of working with a monopolistically competitive market. Later in my empirical model, the fact that the states of the whole market can be summarized into a price index makes my estimation much simpler.[34]

Finally, a firm's total productivity state evolves as

$$\begin{aligned}\omega_{it+1} &= G(\omega_{it}, \rho_{it}) + \varepsilon_{it+1} \\ &= \alpha_0 + \alpha_1\omega_{it} + \alpha_2\omega_{it}^2 + \alpha_3\omega_{it}^3 + \alpha_4\rho_{it} + \varepsilon_{it+1}.\end{aligned} \tag{1.10}$$

The function $G(\cdot)$ is the conditional expectation of future productivity and ε_{it} is a zero mean stochastic shock. This functional form carries some very important information about productivity evolution. First, a firm's productivity persists over time, with the degree of persistence captured by the coefficients α_1, α_2, and α_3. This persistence over time is one of the most important features in firm-level productivity data. Second, I assume that not only the level of productivity can be different for different type of firms as shown in Equation (1.2), but their productivity growth rate can also be different as indicated by the ownership dummy included in Equation (1.10). In

[33] Readers may be confused by the term "price index," which seems to refer to P_t in equation (1.4). In fact, even though PI_t and P_t are different expressions, they are highly correlated with each other. That is also the reason for denoting it with PI_t and naming it the price index. If I substitute a marginal cost function (equation (1.1)) into the optimal price (equation (1.5)), and then into price index P_t (equation (1.4)), I get the following expression,

$$\begin{aligned}P_t &= \frac{\eta}{1+\eta}\left[exp((1+\eta)(\beta_0 + \beta_w W_t))\right]^{\frac{1}{1+\eta}} \left[\sum_{j=1}^{N_t} exp((1+\eta)(\beta_k k_{jt} + \beta_\rho \rho_{jt} + \omega_{jt}))\right]^{\frac{1}{1+\eta}} \\ &= \frac{\eta}{1+\eta}\left[exp((1+\eta)(\beta_0 + \beta_w W_t))\right]^{\frac{1}{1+\eta}} \left[PI_t\right]^{\frac{1}{1+\eta}},\end{aligned}$$

which shows us how PI_t and P_t are related to each other.

[34] Ryan (2012) also tries to aggregate the states of all firms in the market into one number, the total capacity. The introduction of total capacity works very similarly to my price index PI_t.

other words, an SOE and a private firm may realize different future productivities even though they are exactly the same other than their ownership. The magnitude of ownership effects is captured by the coefficient α_4.[35] Third, the specification recognizes the inherent randomness in firms' productivities, which is reflected by the stochastic shock ε_{it+1}. I assume productivity shocks ε_{it+1} are i.i.d. across time and firms, and are drawn from a normal distribution with zero mean and variance σ_{ε}^2. Notice that, because of the first feature above, which elaborates the persistence of productivity, a shock to productivity today will be carried on into the future. The profit function (equation (1.8)) and productivity evolution function (1.10) conclude the discussion of my theoretical model.

1.5 Empirical Strategy

In this section, I estimate the static profit function and productivity evolution process. It is important to explain why I need to estimate productivity evolution process in order to identify the parameters in profit function, rather than working on profit function alone. The short answer is that, unlike ownership and capital level, productivity is unobservable to econometricians. More specifically, the evolutions of ownership and capital, which are observed state variables, can be estimated by reduced-form regressions, but firms' productivity evolution function (equation (1.10)) must be estimated with their revenue function, which implicitly defines unobserved productivities using firms' observed data. To summarize, the key parameters to be estimated in this subsection are the parameters of cost function (β_a, β_k, and β_ρ), the parameters of productivity evolution $(\alpha_0, \alpha_1, \ldots, \alpha_4)$, and the elasticity of demand

[35] Hsieh and Song (2015) have found that "the exit and privatization of state-owned firms had negligible effects on aggregate output growth". However, in Section 1.6, I will show that the results from this paper confirm a positive effect of privatization on firms' productivity. Perhaps, allowing different productivity evolutions among different types of firms is the key for finding such interesting results.

(η).

The optimal pricing function (equation (1.5)) can be rewritten as

$$1 + \frac{1}{\eta} = \frac{exp(c_{it})Q_{it}}{P_{it}Q_{it}},$$

which suggests estimating the elasticity of demand (η) using the ratio of total variable cost to revenue ($\frac{exp(c_{it})Q_{it}}{P_{it}Q_{it}}$), which can be calculated with firms' observable information. It is straightforward to use the average cost-revenue ratio of all firms as an estimate of $1 + \frac{1}{\eta}$. I use $\hat{\eta}$ to denote the estimate of the elasticity of demand η, which can now be derived by the estimate of $1 + \frac{1}{\eta}$.

To estimate $\alpha_0, \alpha_1, \ldots, \alpha_4$, β_a, β_k, and β_ρ, I follow the method proposed by Peters, Roberts, Vuong, and Fryges (2015) in which a proxy variable approach is employed. This approach is pioneered by Olley and Pakes (1996), and its basic idea is that if firms observe their draws of productivity when making production decisions, the chosen amount of variable inputs must be systematically related to their productivities. Therefore, a firm's demand for an intermediate input, for example materials, can be written as a function of TFP and capital, and TFP can be further decomposed into a structural productivity component ω_{it} and ownership type ρ_{it} as in Equation (1.2),

$$m_{it} = f(a_{it}, k_{it}, TFP_{it}) = f(a_{it}, k_{it}, \omega_{it}, \rho_{it}), \tag{1.11}$$

where m_{it} represents log expenditures on intermediate inputs and function f is assumed to be strictly monotonic in ω_{it} for a given a_{it}, k_{it}, and ρ_{it}. The monotonicity of function f ensures the demand for intermediate inputs is invertible such that I can solve for ω_{it} in terms of intermediate inputs, ownership, age, and capital, $\omega_{it} = f^{-1}(a_{it}, k_{it}, m_{it}, \rho_{it})$. Substituting it into equation (1.6), a firm's log revenue can be written as,

$$\begin{aligned} r_{it} &= \sum_{\iota} \gamma_\iota D_\iota + (1+\eta)\left[\beta_a a_{it} + \beta_k k_{it} + \beta_\rho \rho_{it} - \omega_{it}\right] + \upsilon_{it} \\ &= \sum_{\iota} \gamma_\iota D_\iota + (1+\eta)\left[\beta_a a_{it} + \beta_k k_{it} + \beta_\rho \rho_{it} - f^{-1}(a_{it}, k_{it}, m_{it}, \rho_{it})\right] + \upsilon_{it} \qquad (1.12) \\ &= \sum_{\iota} \gamma_\iota D_\iota + h(a_{it}, k_{it}, m_{it}, \rho_{it}) + \upsilon_{it}, \end{aligned}$$

where

$$h(a_{it}, k_{it}, m_{it}, \rho_{it}) = (1+\eta)\left[\beta_a a_{it} + \beta_k k_{it} + \beta_\rho \rho_{it} - f^{-1}(k_{it}, m_{it}, \rho_{it})\right]. \qquad (1.13)$$

D_ι denotes the time dummy for sample year ι, which is used to control for all time invariant terms in equation (1.6) (in this case I_ι and PI_ι), and υ_{it} represents transitory shocks and measurement errors in the firm's revenue. Since a_{it}, k_{it}, and ρ_{it} enter the revenue function through two different channels - (1) directly through the term $\beta_a a_{it}$, $\beta_k k_{it}$, and $\beta_\rho \rho_{it}$, and (2) indirectly through productivity $f^{-1}(a_{it}, k_{it}, m_{it}, \rho_{it})$ - β_a, β_k, and β_ρ cannot be separately identified. To proceed, I introduce h, which encapsulates unobserved function f^{-1}, $\beta_a a_{it}$, $\beta_k k_{it}$, and $\beta_\rho \rho_{it}$, and is written as an unknown function of a_{it}, k_{it}, m_{it}, and ρ_{it}. Replacing $h(a_{it}, k_{it}, m_{it}, \rho_{it})$ with a third-order polynomial of its arguments,[36] equation (1.12) can be estimated with OLS to get estimates of time dummies D_ι.

The results from the previous OLS regression enable us to construct an estimate of the $h(a_{it}, k_{it}, m_{it}, \rho_{it})$ function, $\hat{h}_{it}$, which can further be used to express productivity as,

$$\omega_{it} = -\left(\frac{1}{1+\hat{\eta}}\hat{h}_{it} - \beta_a a_{it} - \beta_k k_{it} - \beta_\rho \rho_{it}\right). \qquad (1.14)$$

I can substitute this expression into the productivity evolution function (equation

[36] I have also tested replacing $h(k_{it}, m_{it}, \rho_{it})$ with higher order polynomials, but the results are not significantly affected.

(1.10)) to find my key regression,

$$\begin{aligned}\hat{h}_{it+1} = \beta_a^* a_{it+1} + \beta_k^* k_{it+1} + \beta_\rho^* \rho_{it+1} - \alpha_0^* + \alpha_1(\hat{h}_{it} - \beta_a^* a_{it} - \beta_k^* k_{it} - \beta_\rho^* \rho_{it}) \\ - \alpha_2^*(\hat{h}_{it} - \beta_a^* a_{it} - \beta_k^* k_{it} - \beta_\rho^* \rho_{it})^2 + \alpha_3^*(\hat{h}_{it} - \beta_a^* a_{it} - \beta_k^* k_{it} - \beta_\rho^* \rho_{it})^3 \\ - \alpha_4^* \rho_{it} - \varepsilon_{it+1}^*, \quad (1.15)\end{aligned}$$

where $\alpha_2^* = \alpha_2 \frac{1}{1+\hat{\eta}}$ and $\alpha_3^* = \alpha_3 \frac{1}{(1+\hat{\eta})^2}$, and all other parameters with an asterisk (β_a^*,β_k^*, β_ρ^*, α_0^*, α_4^*, and ε_{it+1}^*) are the corresponding original parameters times $(1+\hat{\eta})$. Estimating this equation with a non-linear least square regression (NLLS) gives us the estimates of those asterisked parameters, and then the estimates of parameters that I am looking for, $\hat{\alpha}_0, \hat{\alpha}_1, \ldots, \hat{\alpha}_4, \hat{\beta}_\rho, \hat{\beta}_a$ and $\hat{\beta}_k$, can be easily recovered by their definitions.

To recap, I have estimated the parameters $\hat{\eta}$,$\hat{\alpha}_0, \hat{\alpha}_1, \ldots, \hat{\alpha}_4$, $\hat{\beta}_a$, $\hat{\beta}_\rho$, and $\hat{\beta}_k$ in this subsection. With all these estimates in hand, I am able to calculate each firm's productivity using

$$\hat{\omega}_{it} = -(\frac{1}{1+\hat{\eta}}\hat{h}_{it} - \hat{\beta}_a a_{it} - \hat{\beta}_k k_{it} - \hat{\beta}_\rho \rho_{it}). \quad (1.16)$$

The static profit of each firm $\bar{\pi}_{it}$ can also be calculated from its definition (equation (1.8)).[37]

1.6 Empirical Results

In this section, I present the estimates of static profit function and productivity evolution function. I adopt several different models and the estimates are compared with each other in order to find the most reasonable ones to use.

[37]Interested readers are encouraged to consult Peters, Roberts, Vuong, and Fryges (2015) for two differences between their model and the one developed by Olley and Pakes (1996). The differences mentioned there also apply to my model. Briefly speaking, my model (1) assumes productivity evolution as an exogenous process and (2) sidesteps the necessity of estimating a production function.

1.6.1 Static Profit

The key parameters to be estimated for the static profit function $\bar{\pi}$ are fixed time effects $\gamma_1, \gamma_2, \ldots, \gamma_{10}$, elasticity of demand η, marginal cost change in age β_a, cost elasticity of capital β_k, and the difference in marginal costs between private and state-owned firms β_ρ. The results are presented in Table 1.6. In this table, I show the numbers derived from two different models. The second column presents the results of a simple OLS, regressing each firm's main operation revenue r_{it} on time dummies $D_1, D_2, \ldots, D_{10}$, age a_{it}, log real capital k_{it}, and a private ownership dummy ρ_{it}.[38] The numbers in the third column are the estimates of my empirical model in the previous section.

Because the regressions used are completely different between OLS and my model, I am not surprised to see different sets of time fixed effects. However, both models reflect that firms become more capable of generating sales and revenues over the years. This is consistent with the story of China's successful market transformation and GDP growth, which makes people more prosperous and endows them with greater purchasing power.

$1 + \frac{1}{\eta}$ is estimated the same way in both models and its value is 0.894, implying an elasticity of demand $\eta = -9.452$. Demand elasticity is an important piece of information about firms' ability to convert productivity into profit, as seen in equation (1.8). Notice that, given a demand function defined in equation (1.3), the elasticity of substitution is equal to $-\eta = 9.452$, which measures to what degree two goods or services can be substitutes for one another.[39] More simply, it tells us how easy it is for a consumer to substitute one good for another. The Electronic and Telecommunications Industry is relatively competitive and firms produce substitutable products.

[38]This is the model presented in the first line of equation (1.12).

[39]The detailed derivation of the elasticity of substitution for this model can be found in the appendix.

Therefore, a high level of elasticity of substitution is expected. This number is also comparable to the one reported in Jaumandreu and Yin (2016), in which, estimated using exactly the same dataset, the Electronics Industry has an elasticity of substitution of 6.1 in the domestic market and 10.7 in the foreign market.

The cost elasticity of capital β_k is estimated to be -0.073 in OLS and -0.029 in my model. Negative values of β_k imply that firms with higher capital stocks have lower production costs because they are able to use less variable inputs, for example labor and material, to produce the same amount of goods. To interpret the numbers in a more straightforward way, I calculate implied input elasticity of capital using the cost minimization model presented in the appendix (equation (1.23)). The implied input elasticity α_k measures the responsiveness of output to a change in levels of capital used in production. $\alpha_k = 0.029$ reported in my model means that a 1% increase in capital usage would lead to approximately a 0.029% increase in output. Once again, this number is comparable to the one estimated in Jaumandreu and Yin (2016), 0.077.

Finally in this table, I report the estimates of β_ρ which are -0.061 and -0.022 in simple OLS and in my model respectively. According to equation (1.2), the negative numbers confirm the observation that private firms are more efficient than their state-owned counterparts. Other than indicating that private firms are more productive, the coefficients themselves do not mean anything if we do not examine the other component of total factor productivity, ω_{it}. I do this in the next subsection.

1.6.2 Productivity Evolution

To characterize productivity evolution (equation (1.10)), I estimate its parameters $\alpha_0, \alpha_1, \ldots, \alpha_4$. The results are presented in Table 1.7. The persistence of firms' productivity level is measured by the coefficients of ω_{it}, and of its squared and cubed terms. In this case, it is highly persistent since the marginal effects of ω_{it} on ω_{it+1} for an average firm (with productivity level of 0.274) is 0.948.[40] The effects are not linear as the effects of the squared and cubed terms are statistically significant. I also find that a private enterprise is more likely to realize a higher productivity in the next period than an SOE with the same level of current productivity. This result is in accordance with other papers in the literature, for example, Bai, Lu, and Tao (2009).

With firms' estimated productivities calculated by equation (1.16), I am able to summarize in Table 1.8 the industry-level productivities across firms with different ownerships. More specifically, I classify firms into five different groups. "SOEs" and "private firms" contain state-owned and private observations, respectively. I separate SOEs into two types, (1) the SOEs that were eventually privatized and (2) those that had never been privatized. The latter form a group called "non-privatized SOEs," and the former are further divided into observations before privatization and those after, called "privatized SOEs before privatization" and "privatized SOEs after privatization," respectively.

As we can see from this table, there are many more private observations (39,852) than state-owned ones (3,858) due to a large number of private start-ups and privatizations, and private firms on average appear to be more productive than SOEs by 20.716% and 23.283%, if calculated with unweighted and capital-weighted means respectively. These results are not surprising because SOEs are considered to be old, decaying and lacking vitality during my sample period. As predicted by my theoretical model, these percentage differences in productivity are much smaller than those estimated in some other studies, for example, 171.7% estimated by Chen, Igamiz, Sawada, and Xiao (2017).[41] It confirms that a method that does not take into account

[40] I take the derivative of equation (1.10) with respect to ω_{it} to obtain the equation for marginal effect, $\alpha_1 + 2\alpha_2\omega_{it} + 3\alpha_3\omega_{it}^2$.

[41] In their paper, data for China's Electronic and Telecommunications Industry shows that private firms are 171.7% more efficient than SOEs, and the full sample with firms in all industries gives an even more dramatic productivity difference, 229%.

differences in input prices may overestimate the productivity difference between the two types of firms, and the degree of overestimation can be as large as 148 percentage points.

The SOEs selected for privatization ("privatized SOEs before privatization") have a higher average productivity than SOEs that do not go through the privatization process ("non-privatized SOEs"). This is consistent with my findings in section 2.5.3 later in this paper that governments are more likely to privatize more highly productive SOEs, but more likely to terminate less productive ones that are unlikely to survive on their own once privatized.[42] The main reason for governments conducting such a selective privatization process is to maintain a relatively high success rate by personalizing treatments.

In particular, I am very interested in comparing the productivity distribution of two groups, "privatized SOEs before privatization" and "privatized SOEs after privatization", because it reflects the direct effects of privatization on firms' productivity. In general, SOEs see 16.741% (19.267% without weighting) improvement in productivity once privatized. The histograms of these two groups are plotted in the left panels of Figure 1·4, along with their corresponding probability density functions (PDFs) in the right panels derived by a kernel density estimation with a normal kernel smoothing function and optimal bandwidth for normal density. Plus, to make the figures mare comparable, I plot dotted vertical lines to indicate zero productivities and solid vertical lines to label mean levels. We can see from the graphs that the mass of productivity distribution after privatization shifted to the right compared to that before privatization, indicating improvements in SOEs' productivities once privatized.[43]

[42]Notice that the sample size of "privatized SOEs before privatization" and "non-privatized SOEs" sum to the number of "SOEs". In addition, since there are 39,852 observations in "private firms" and 866 observations in "privatized SOEs after privatization", the number of observations of permanent private firms can be calculated by their difference, which is 38,986.

[43]Note that there are clearly fewer observations before privatization than after, since ownership changes occurred mostly in the first several years into my sample period. According to Table 1.8,

Since it may be difficult to compare them with the naked eye, I superimpose in Figure 1·5 the two PDFs from the right two panels of Figure 1·4, from which the relationship described above is very clear.

In fact, the presented method above that compares the productivity between "SOEs" and "private firms" does not exclude the selection effect. In contrast, I will compare their productivity using a different approach in this paragraph. Specifically, I start with two firms with average productivity measure in 1996 ($\omega = 0.211$), and one firm is private and the other is state-owned. Then I calculate how their productivity will evolve differently according to estimated productivity evolution function, Equation (1.10). Finally, their TFP are calculated and plotted against time in Figure 1·3. The top panel shows TFP evolution over time for these two types of firms. While the SOE slowly improves its productivity level, the private firm becomes more efficiency with a much faster pace by 55.159% (from 0.252 in 1997 to 0.391 in 2006). In the bottom panel, I plot the percentage differences in productivity between them. At the begin of our sample period, the private firm is only 9.239% more productive than the SOE, and ten years later, the difference become quite large, 36.913%. On average across ten years, private firm is 20.783% more productive than the SOE. Even though we see larger difference in this approach, they are not as large as 171.7% estimated by Chen, Igamiz, Sawada, and Xiao (2017). Again, this shows the advantage of this model, that is being able to derive more reasonable productivity measures.

1.7 Conclusion

In this paper, I construct a simple static competition model to study firms' productivity in China during recent economic reform. Specifically, I focus on the differences in input prices among different types of firms and believe that they are in fact very

there are 576 observations in the first group and 866 observations in the second. However this does not affect my conclusion that the mass of productivity shifted to the right after privatization.

important for explaining the reform. The model is estimated with the technique proposed by Peters, Roberts, Vuong, and Fryges (2015) and the results confirm my expectation that SOEs are less efficient than private firms, but by not as much as we were led to believe when input prices were not incorporated into the analysis.

1.8 Appendix

1.8.1 Construction of Firms' Real Capital

To construct the measure of firms' real capital measure, I follow a five-step process.

1. I find the industry average fixed asset value in 1993 and calculate the average rate of growth in nominal capital stock at the industry level between 1993 and 1997. Then I can estimate the yearly nominal capital growth rate from 1993 to 1997 by simply assuming the growth rates are equal in all years. In addition, the yearly growth rate between 1997 and 2006 can be calculated directly from the data.

2. For each firm, I discount its fixed asset value reported in the last available year using the growth rates calculated in step 1, to obtain a measure of its nominal capital at birth.

3. I use the information calculated from steps 1 and 2 to obtain a nominal capital for each firm from its birth year to the last year it appears in my data set.

4. The difference in nominal capital between two consecutive years can be thought of as nominal investment. Then real investment is derived by discounting nominal investment using the Brandt-Rawski deflator.[44]

5. Finally, a firm's real capital stock for each year can be calculated using the perpetual inventory method, $K_{it} = \sum_{\tau=0}^{\tau=t}(1-\delta)^{\tau} \times I_{i\tau}$, which means the real capital of firm i at time t is the summation of all real investments I (depreciation accounted) from its birth year to the current year.

[44] See Brandt, Van Biesebroeck and Zhang (2012).

1.8.2 Marginal Cost Function Derived from Cost Minimization

By making some minor assumptions concerning firms' cost-minimizing behaviors, I can derive a marginal cost function independent of total output. This section presents one such example. First, I assume that an incumbent firm i determines how to produce a certain amount of output Q_{it} in period t by choosing the level of labor and material so as to minimize its total cost (TC_{it}) of producing Q_{it}. Thus the problem faced by each firm is as follows,

$$\begin{aligned} \underset{L,M}{\text{minimize}} \quad & TC_{it} = r_t K_{it} + w_t L_{it} + \tau_t M_{it} \\ \text{subject to} \quad & Q_{it} \leq exp(TFP_{it}) L_{it}^{\alpha_L} K_{it}^{\alpha_K} M_{it}^{\alpha_M} \end{aligned} \tag{1.17}$$

where K, L, and M are firm's real capital, labor, and material (not logged) used in production, respectively, and r, w, and τ are the prices of these components.[45] Production technology follows Cobb-Douglas with input elasticities α_L, α_K, and α_M. TFP is the firm's total factor productivity.

To solve the minimization problem, I set up Lagrange, take derivatives with respect to L and M, and solve the system of equations for the optimal level of two choice variables, labor L and material M. To simplify the notation, I suppress the time subscript of variable prices.

$$L_{it} = \left[\frac{\tau}{w}\right]^{\frac{\alpha_M}{\alpha_M+\alpha_L}} \cdot \left[\frac{\alpha_L}{\alpha_M}\right]^{\frac{\alpha_M}{\alpha_M+\alpha_L}} \cdot exp(TFP_{it})^{\frac{-1}{\alpha_M+\alpha_L}} \cdot K_{it}^{\frac{-\alpha_K}{\alpha_M+\alpha_L}} \cdot Q_{it}^{\frac{1}{\alpha_M+\alpha_L}} \tag{1.18}$$

$$M_{it} = \left[\frac{\tau}{w}\right]^{\frac{-\alpha_L}{\alpha_M+\alpha_L}} \cdot \left[\frac{\alpha_L}{\alpha_M}\right]^{\frac{-\alpha_L}{\alpha_M+\alpha_L}} \cdot exp(TFP_{it})^{\frac{-1}{\alpha_M+\alpha_L}} \cdot K_{it}^{\frac{-\alpha_K}{\alpha_M+\alpha_L}} \cdot Q_{it}^{\frac{1}{\alpha_M+\alpha_L}} \tag{1.19}$$

Then I substitute the two equations above into a total cost function to obtain the

[45] I can also think of the last input as intermediate input in general.

following expression,

$$TC_{it} = rK_{it} + \left(\left[\frac{\alpha_L}{\alpha_M} \right]^{\frac{\alpha_M}{\alpha_M+\alpha_L}} + \left[\frac{\alpha_L}{\alpha_M} \right]^{\frac{-\alpha_L}{\alpha_M+\alpha_L}} \right) \cdot w^{\frac{\alpha_L}{\alpha_M+\alpha_L}} \cdot \tau^{\frac{\alpha_M}{\alpha_M+\alpha_L}} \cdot exp(TFP_{it})^{\frac{-1}{\alpha_M+\alpha_L}} \cdot K_{it}^{\frac{-\alpha_K}{\alpha_M+\alpha_L}} \cdot Q_{it}^{\frac{1}{\alpha_M+\alpha_L}}. \quad (1.20)$$

I take the derivative with respect to output Q_{it} to get marginal cost (C_{it}),

$$C_{it} = A \cdot w^{\frac{\alpha_L}{\alpha_M+\alpha_L}} \cdot \tau^{\frac{\alpha_M}{\alpha_M+\alpha_L}} \cdot exp(TFP_{it})^{\frac{-1}{\alpha_M+\alpha_L}} \cdot K_{it}^{\frac{-\alpha_K}{\alpha_M+\alpha_L}} \cdot Q_{it}^{\frac{1-(\alpha_M+\alpha_L)}{\alpha_M+\alpha_L}} \quad (1.21)$$

where

$$A = \frac{1}{\alpha_M + \alpha_L} \left(\left[\frac{\alpha_L}{\alpha_M} \right]^{\frac{\alpha_M}{\alpha_M+\alpha_L}} + \left[\frac{\alpha_L}{\alpha_M} \right]^{\frac{-\alpha_L}{\alpha_M+\alpha_L}} \right).$$

Finally I take the log on both sides to find an expression for marginal cost,

$$log(C_{it}) = log(A) + \frac{\alpha_L}{\alpha_M + \alpha_L} log(w) + \frac{\alpha_M}{\alpha_M + \alpha_L} log(\tau) - \frac{1}{\alpha_M + \alpha_L} TFP_{it} - \frac{\alpha_K}{\alpha_M + \alpha_L} log(K_{it}) + \frac{1 - (\alpha_M + \alpha_L)}{\alpha_M + \alpha_L} log(Q_{it}). \quad (1.22)$$

To make marginal cost independent of output, I need to assume that $\alpha_M + \alpha_L = 1$. This is in fact what Peters, Roberts, Vuong, and Fryges (2015) and many other papers assumed implicitly. As long as a paper presents a marginal cost that is not a function of output, some implicit restrictions on input elasticities must be in place, even though the papers do not discuss those restrictions explicitly. In China's Electronic and Telecommunications Industry, the restriction that α_M and α_L sum to 1 can be backed up by Jaumandreu and Yin (2016), who estimate the joint distribution of unobserved productivity (cost advantages) and unobserved demand heterogeneity (product advantages) for Chinese manufacturing firms from 1998 to 2008. That paper uses exactly same data set as mine, and the production function estimates for the Electronic and Telecommunications Industry show us that the sum of labor and material input elasticity is 0.959 ($\alpha_L = 0.505$ and $\alpha_M = 0.454$). Then I take the assumption above into account and simplify equation (1.22) to obtain

$$log(C_{it}) = log(A) - \frac{\alpha_K}{\alpha_M + \alpha_L} log(K_{it}) + \frac{\alpha_L}{\alpha_M + \alpha_L} log(w) + \frac{\alpha_M}{\alpha_M + \alpha_L} log(\tau) - \frac{1}{\alpha_M + \alpha_L} TFP_{it}$$

which simplifies to

$$c_{it} = \beta_0 + \beta_k k_{it} + \beta_w W - \frac{1}{\alpha_M + \alpha_L} TFP_{it} \tag{1.23}$$

where

$$\beta_0 = log(A)$$
$$\beta_k = -\frac{\alpha_K}{\alpha_M + \alpha_L}$$
$$\beta_w = [\frac{\alpha_L}{\alpha_M + \alpha_L}, \frac{\alpha_M}{\alpha_M + \alpha_L}]$$
$$W = [log(w), log(\tau)]'.$$

I use lower case c and k to represent the log of the corresponding upper case variables.

Comparing my simplified log marginal cost (equation (1.23)) with the assumed functional form (equation (1.1)), as long as I redefine the productivity term to be $\frac{1}{\alpha_M+\alpha_L} TFP_{it}$, I find that they are exactly the same. Hence, a marginal cost that is independent of output (equation (1.1)) is derived.

1.8.3 Optimal Price Derived from Profit Maximization

Since I assume that marginal cost is not a function of output (equation (1.1)), total cost can be written as $TC_{it} = exp(c_{it})Q_{it}$. Therefore, each firm has to solve the following unconstrained profit maximization problem,

$$\underset{P_{it}}{\text{mzximize}} \;\; P_{it}Q_{it} - exp(c_{it})Q_{it}$$

I substitute the demand function (equation (1.3)), and take the derivative with respect to price. I then have the optimal price (equation (1.5)).

1.8.4 Profit Function in Terms of Revenue

In my model, profit can be expressed as a function of revenue only, thanks to the assumption that marginal cost is not a function of output (equation (1.1)). Continuing with the profit function from the previous subsection in the appendix and replacing price P_{it} with the optimal pricing function (equation (1.5)), we have

$$\begin{aligned}
\bar{\pi}_{it} &= P_{it}Q_{it} - exp(c_{it})Q_{it} \\
&= \frac{\eta}{1+\eta}exp(c_{it})Q_{it} - exp(c_{it})Q_{it} \\
&= (\frac{\eta}{1+\eta} - 1)exp(c_{it})Q_{it} \\
&= -\frac{1}{\eta} \cdot \frac{\eta}{1+\eta}exp(c_{it})Q_{it}
\end{aligned}$$

Notice that $\frac{\eta}{1+\eta}exp(c_{it})$ is just the optimal price (equation (1.5)). Therefore,

$$\bar{\pi}_{it} = -\frac{1}{\eta} \cdot P_{it}Q_{it} = -\frac{1}{\eta} \cdot exp(r_{it}).$$

1.8.5 Elasticity of Substitution

Given demand equation (1.3), I can calculate the elasticity of substitution between good i and good j. Firstly, the ratio of the two good quantities is

$$\frac{Q_{it}}{Q_{jt}} = \left(\frac{P_{jt}}{P_{it}}\right)^{-\eta}.$$

Then elasticity of substitution is defined by

$$\begin{aligned}
\frac{ln(\frac{Q_{it}}{Q_{jt}})}{ln(MRS^t_{ij})} &= \frac{d(\frac{Q_{it}}{Q_{jt}})}{d(\frac{P_{jt}}{P_{it}})} \cdot \frac{\frac{P_{jt}}{P_{it}}}{\frac{Q_{it}}{Q_{jt}}} \\
&= -\eta(\frac{P_{jt}}{P_{it}})^{-\eta-1}\frac{P_{jt}}{P_{it}}(\frac{P_{it}}{P_{jt}})^{-\eta} \\
&= -\eta,
\end{aligned}$$

where MRS^t_{it} is the marginal rate of substitution between good i and good j at time t.

Table 1.1: Summary Statistics

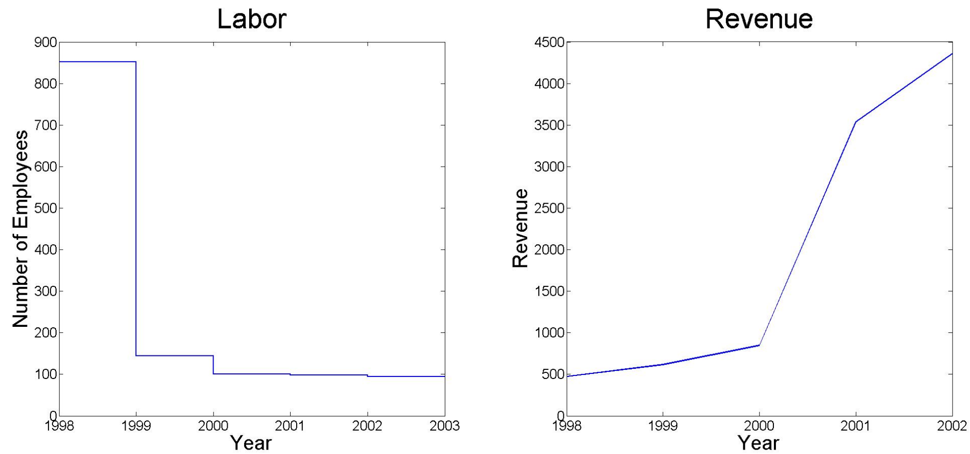
Year	Main Operation Revenue	Main Operation Cost	Intermediate Input	Real Capital	Num of Labor	Num of Observations
1998	118.654	105.478	103.707	43.927	495.904	1983
	(497.882)	(426.410)	(486.667)	(146.432)	(1126.030)	
1999	144.414	129.506	117.317	48.609	499.876	2275
	(595.385)	(535.344)	(515.072)	(188.544)	(1122.998)	
2000	173.329	153.551	139.538	49.721	479.244	2686
	(740.370)	(652.035)	(609.864)	(211.942)	(1042.642)	
2001	191.333	174.452	153.445	50.638	425.635	2976
	(901.879)	(831.075)	(730.571)	215.078	831.821	
2002	216.601	196.837	179.374	55.509	443.185	3452
	(1130.465)	(1044.169)	(1008.011)	(255.949)	(925.683)	
2003	299.074	298.210	235.699	61.597	489.882	3956
	(1748.422)	(1746.996)	(1506.282)	(321.545)	1109.802	
2004	270.450	251.128	215.494	58.414	452.485	6419
	(1838.011)	(1745.671)	(1498.272)	(382.420)	(1336.322)	
2005	302.806	282.367	243.577	66.144	510.309	6944
	(2207.210)	(2100.961)	(1934.490)	(398.780)	(1737.819)	
2006	368.103	343.381	295.103	78.917	583.351	6722
	(2736.801)	(2610.509)	(2379.541)	(439.956)	(2291.027)	
2007	446.285	414.993	365.317	94.196	662.874	6297
	(3443.908)	(3270.436)	(3014.854)	(508.358)	(3155.160)	
overall	289.476	269.704	233.685	65.778	519.009	43710
	(2152.953)	(2050.320)	(1865.222)	(370.417)	(1845.158)	

Mean values are reported for each variable along with their standard errors in the paraphrases.
The units of all values are million RMB, except for the number of labors and the number of observations.

Table 1.2: Firm Ownership Statistics

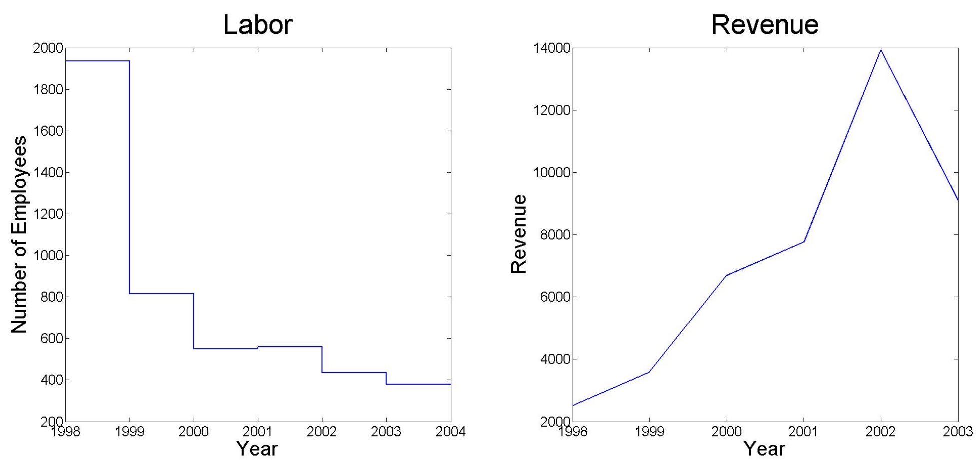
Year	Num of Firms	Num of SOEs	Num of Private Firms	Percentage of SOEs
1998	1983	523	1460	26.374%
1999	2275	503	1772	22.110%
2000	2686	502	2184	18.690%
2001	2976	396	2580	13.306%
2002	3452	394	3058	11.414%
2003	3956	350	3606	8.847%
2004	6419	345	6074	5.375%
2005	6944	330	6614	4.752%
2006	6722	286	6436	4.255%
2007	6297	229	6068	3.637%
overall	43710	3858	39852	8.826%

Figure 1·1: Mass Layoff Example (One Time Layoff)



Left panel shows the number of employees for "Kai Feng Guang Sha Electronics Production Ltd." over sample years. The number of employees is on vertical axis and year is on horizontal axis. Right panel depicts the revenues for the same company in the same period. The revenue (in thousands of RMBs) is on vertical axis and year is on horizontal axis. "Kai Feng Guang Sha Electronics Production Ltd." is an example of firms which pursue a one time mass layoff. This is the most common types of mass layoff process out there in China's Electronic and Telecommunications industry.

Figure 1·2: Mass Layoff Example (Two Consecutive Layoffs)



Left panel shows the number of employees for "Wuhan Zhongyuan Electronics Group Co." over sample years. The number of employees is on vertical axis and year is on horizontal axis. Right panel depicts the revenues for the same company in the same period. The revenue (in thousands of RMBs) is on vertical axis and year is on horizontal axis. "Wuhan Zhongyuan Electronics Group Co." is an example of the firms which carry out two consecutive mass layoffs. This is the second most common types of mass layoff process out there in China's Electronic and Telecommunications industry.

Table 1.3: Evidences of Mass Layoffs

Parameters	Model 1	Model 2
const	64.012	15.268
	(3.983)***	(3.426)***
Labor		0.046
		(0.004)***
$Labor^2$		$2.720 * 10^{-6}$
		$(0.040 * 10^{-6})$***
$D2$	-47.370	-53.797
	(47.565)	(37.528)
$D3$	-96.445	-111.232
	(13.537)***	(10.712)***
Capital		$5.078 * 10^{-6}$
		$9.686 * 10^{-6}$
Wage		0.002
		(0.000)***
R-square	0.001	0.378
Num of Priv to Priv	32009	32009
Num of SOE to Priv	226	226
Num of SOE to SOE	3033	3033
sample size	35268	35268

Standard errors are in paraphrases.
* significant at 10%, ** significant at 5%, *** significant at 1%.

Table 1.4: Counting Consecutive Mass Layoffs

Layoff Size	One layoff	Two Layoffs	Three Layoffs	Sample Size
$> 10\%$	295	117	57	712
$> 20\%$	284	58	16	712
$> 30\%$	229	33	2	712
$> 40\%$	163	15	1	712
$> 50\%$	106	9	0	712
$> 60\%$	77	3	0	712
$> 70\%$	50	1	0	712
$> 80\%$	31	0	0	712

Table 1.5: Productivity Change After Dealing With Mass Layoff

Layoff Size	Prod Before	Prod After	Prod Change	% Change	No. Obs	No. Dropped
> 10%	63.639	71.667	8.028	12.615%	3259	801
> 20%	63.639	67.032	3.393	5.332%	3259	503
> 30%	63.639	66.128	2.489	3.911%	3259	334
> 40%	63.639	65.010	1.371	2.154%	3259	219
> 50%	63.639	64.733	1.094	1.719%	3259	142
> 60%	63.639	64.632	0.993	1.560%	3259	92
> 70%	63.639	64.173	0.534	0.840%	3259	59
> 80%	63.639	63.970	0.331	0.521%	3259	33

Productivities are in thousands of RMBs per worker.

Table 1.6: Static Profit Parameters

Parameters	OLS	My Modle
$1+\frac{1}{\eta}$	0.894	0.894
	(0.360)***	(0.360)***
β_a	0.002	0.011
	(0.000)***	(0.000)***
β_k	-0.073	-0.029
	(0.000)***	(0.001)***
β_ρ	-0.061	-0.022
	(0.003)***	(0.004)***
γ_1	4.294	6.734
	(0.041)***	(0.206)***
γ_2	4.349	6.747
	(0.041)***	(0.206)***
γ_3	4.450	6.764
	(0.040)***	(0.206)***
γ_4	4.467	6.766
	(0.040)***	(0.206)***
γ_5	4.511	6.773
	(0.040)***	(0.206)***
γ_6	4.639	6.800
	(0.039)***	(0.206)***
γ_7	4.606	6.832
	(0.037)***	(0.206)***
γ_8	4.660	6.841
	(0.038)***	(0.206)***
γ_9	4.753	6.858
	(0.038)***	(0.206)***
γ_{10}	4.849	6.869
	(0.039)***	(0.206)***
implied profit margin $(\frac{\eta}{1+\eta}-1)100\%$	11.857%	11.857%
implied elasticity of demand η	-9.452	-9.452
implied elasticity of substitution $-\eta$	9.452	9.452
implied input elasticity α_K	0.073	0.029
sample size	35268	35268

Standard errors are in paraphrases.
* significant at 10%, ** significant at 5%, *** significant at 1%.

Table 1.7: Productivity Evolution Parameters

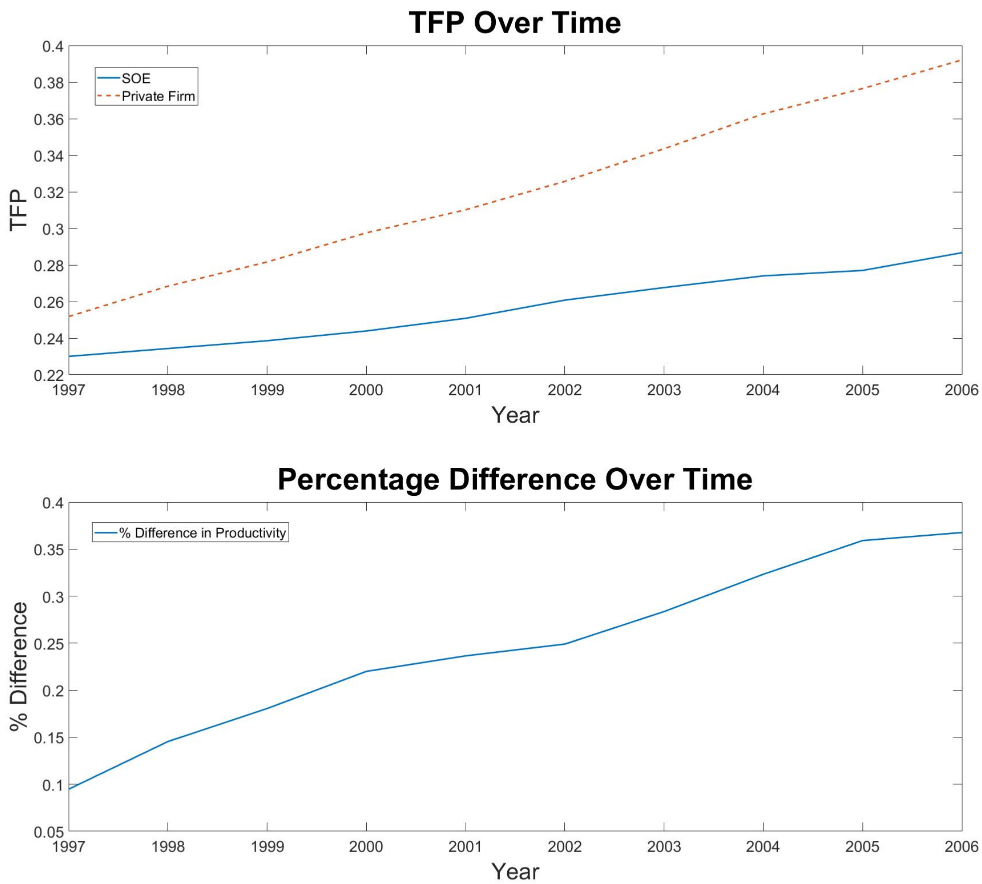
Parameters	My Model
$const$	0.050 (0.003)***
ω_{it}	0.675 (0.012)***
ω_{it}^2	0.644 (0.030)***
ω_{it}^3	-0.382 (0.027)***
ρ_{it}	0.011 (0.001)***
sample size	35268

Standard errors are in paraphrases.
* significant at 10%, ** significant at 5%, *** significant at 1%.

Table 1.8: Mean Productivity Across Ownership Type

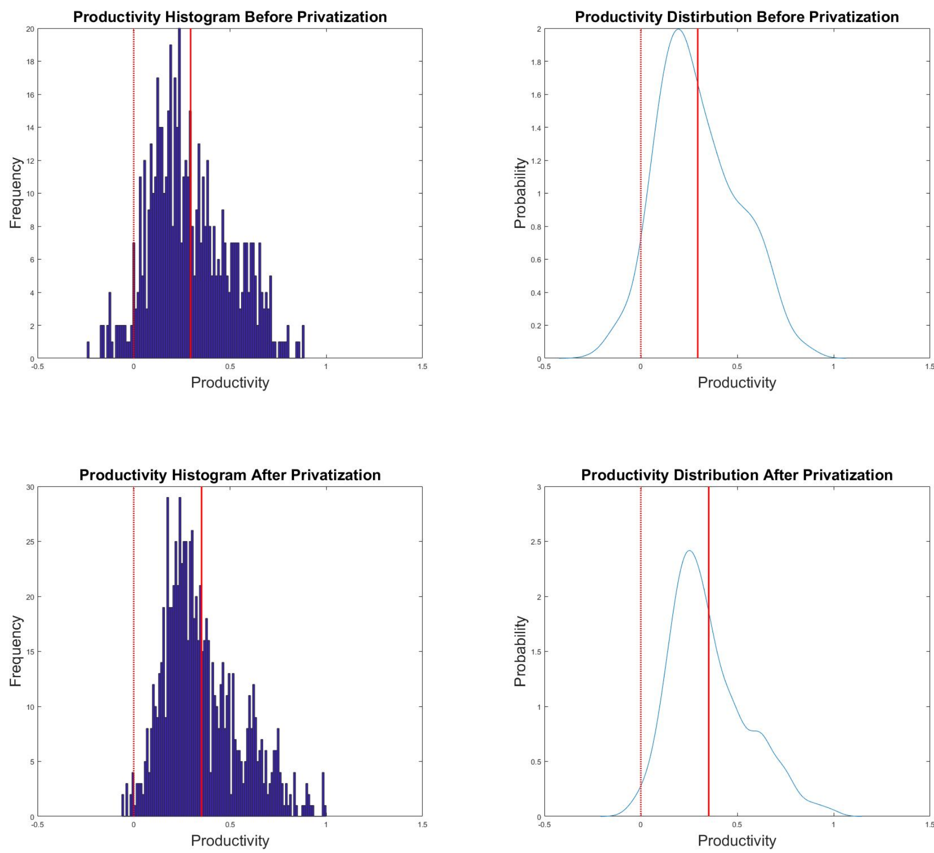
Parameters	Mean	Capital Weighted Mean	Median	SE	Sample Size
SOEs	0.268	0.286	0.271	0.157	3858
private firms	0.338	0.373	0.313	0.252	39852
privatized SOEs before privatization	0.295	0.320	0.263	0.210	576
privatized SOEs after privatization	0.352	0.374	0.307	0.200	866
non-privatized SOEs	0.346	0.381	0.325	0.258	3282
all Firms	0.274	0.294	0.241	0.169	43710
Productivity % difference between SOEs and private firms	20.716%	23.283%			
Productivity % change from SOEs to private firms	19.267%	16.741%			

Figure 1·3: Productivity Evolution for Two Average Firms with Different Ownership



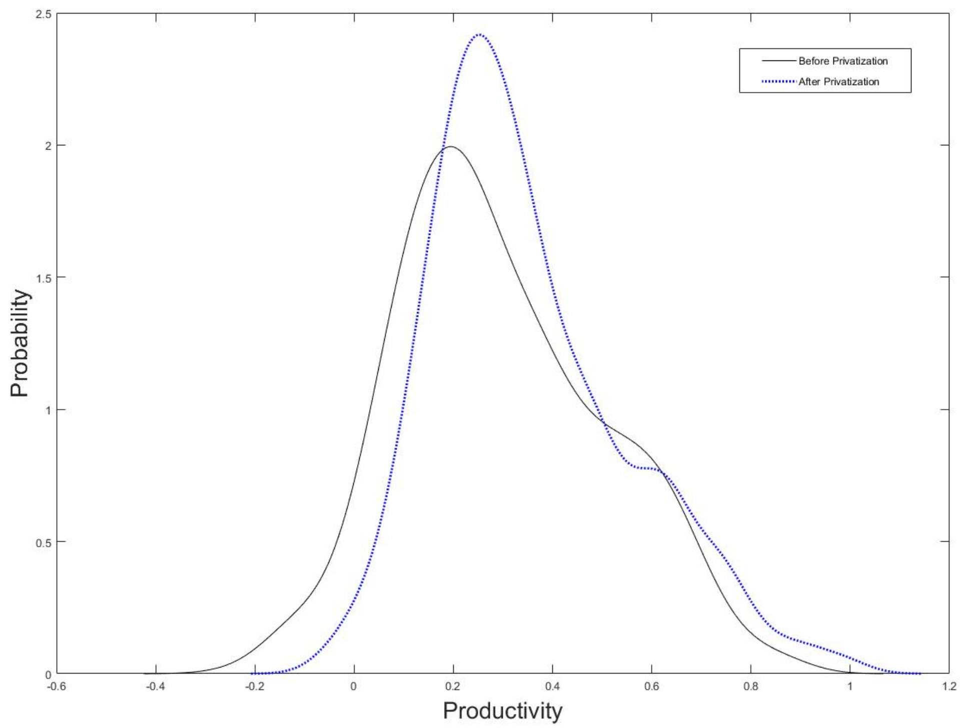
Top panel shows TFP evolution for these two types of firms. The TFP is on vertical axis and time is on horizontal axis. Bottom panel is the percentage difference in productivity between these two types of firms in different years. The percentage difference in productivity is on vertical axis and time is on horizontal axis.

Figure 1·4: Productivity Distribution of All Privatized SOEs Before and After Privatization



Top-left panel shows the TFP histogram of privatized SOEs before privatization in my dataset. Top-right panel depicts the probability density function estimated using the same dataset. Bottom-left panel shows the TFP histogram of privatized SOEs after privatization in my dataset. Bottom-right panel depicts the probability density function estimated using the same dataset. I draw a dotted vertical line to indicate zero TFP and a solid vertical line to label mean levels of productivity. Total Factor Productivity (TFP) is on horizontal axises in all graphs. The number of observations is on vertical axis in the left two graphs and probability is on vertical axis in the right two graphs.

Figure 1·5: Compare Productivity Distribution Before and After Privatization



Solid line represents PDF of TFP for privatized SOEs before privatization. Dotted line represents PDF of TFP for privatized SOEs After privatization. Total Factor Productivity (TFP) is on horizontal axises and probability is on vertical axis.

Chapter 2

Privatization and the Dynamics of Productivity and Investment in China since 1990

2.1 Introduction

Even though the differences in input prices are well documented, there is a lack of empirical evidences supporting it.[1] The reason for such difficulty is that we do not observe the corresponding information in the dataset. A firm's level of liability is observable but not its price. Furthermore, we do not know the amount of subsidies provided to SOEs. In order to empirically prove that SOEs are granted easy access to credits comparing to private firms, a structural model can be very helpful, and firms' investment behavior can be used to pin down the input costs of different types of firms for further comparison.

In this chapter, I build such a dynamic structural model that integrates the fact that state-owned and private firms incur different investment prices, as well as many other important factors including government reform policies, heterogeneous firm characteristics, and macroeconomic market conditions. Since such a difference in input prices affects firms' decisions in a dynamic fashion, especially when governments are particularly selective on firm' size when deciding which SOEs are to be privatized, we draw on the fully dynamic workhorse industry evolution models by Hopenhayn

[1] All evidences provided in my first chapter of this dissertation, as well as all other papers in the literatures, are not empirical. They are mainly from experiences and policy statements.

(1992) and Ericson and Pakes (1995).[2] The model is used to study firms' dynamic behaviors and market transformation in China during reform and look at the effect of policy changes on the market. The parameters of the model are estimated using an unbalanced panel data set of China's Electronic and Telecommunications Industry from 1997 to 2006 extracted from the "Chinese Industrial Enterprises Database". [3] Because of such a large pool of possible states in our model, we use the two-step estimation process proposed by Bajari, Benkard, and Levin (2007) (BBL) to reduce the computational burden. The estimation results provide significant evidences of input price differences and correctly reflect many other well documented institutional regularities. Finally, simulations are carried out to study the effects of many interesting alternative policies.

This chapter differs from the literature in the following aspects. First, this is the first dynamic structural model in the literature to study the transformation of the market during the reform in China. Second, firm entry is explicitly modeled in order to incorporate the effects of policy that encourages the formations of new private firms. Third, while many other papers implicitly assume that privatization and termination decisions are made by the SOEs themselves, I limit these decisions solely to governments for a more accurate rendering. Furthermore, SOEs' privatization decisions are modeled as probabilities of being selected by governments for reform, and this innovative modeling choice greatly simplifies the estimation process of the model.

In this chapter, I study China's reform using a dynamic structural model that has non-negligible advantages over reduced-form regressions, which lie in the capability to simulate hypothetical policy changes and answer many types of questions that cannot

[2]The literature on privatization and ownership change has long acknowledged selection bias as a major econometric problem. It is more evident in the case of China where a specific policy, "grasp the large and let go of the small," has been designed to guide the selection process in a certain direction. The policy itself is a very important part of this paper and will be discussed in much detail in later sections.

[3]This dataset is the same as the previous chapter.

be easily solved with simple regressions.[4] Therefore, at the end of the paper, I simulate market evolution under different circumstances and answer some very important questions about policy changes. I start with the question what would happen if SOEs were not given easy access to credit. In other words, SOEs are forced to pay a higher price for investment. The second group of questions involves different government selection schemes for reform. Firstly, the governments' privatization and termination decisions are highly selective based on firm size, as epitomized in "grasp the large, let go of the small." It would be very interesting to ask what if governments reverse the roll of firm size to the chance of being selected for reform. Second, the reform policies are proven later in the paper to be selective based on firm productivity. It is certainly worth checking how the market would react if there were no preference on firm efficiency. The last question involves the two main channels of government market reform, (1) encouraging new entrants and (2) privatizing existing SOEs. With the help from my structural model, I am able to isolate the effects of one channel from the other.

The structure of the paper is as follows. In section 2.2, I provide a brief description of the data set and present some preliminary evidences of easy access to credits for SOEs. Section 2.3 presents my theoretical model of privatization, firm heterogeneity, and industry evolution. Section 2.4 develops a two-stage estimation method for the model. The first stage estimates the policy functions and underlying processes of firms' productivity and ownership; the second stage uses these results as well as equilibrium conditions to derive the dynamic parameters of the model. Section 2.5 summarizes the parameter estimates and explains their validity. Section 2.6 uses my

[4] In fact, being able to perform simulation is one of the reasons why I started with a dynamic structural model rather than reduced-form regressions. Regressions are good at investigating the effects of policies that have actually been implemented, but are limited in explaining the effects of a hypothetical policy. This is mainly because we have no data available for a market evolving under hypothetical policies that have never been carried out.

estimated model to simulate alternative policies and answer some important questions about China's economic reform. Section 3.5 concludes.

2.2 Data Set and Summary Statistics

The data used in this chapter is exactly the same as the one in previous chapter. The details about how I process the raw data into a set of data entries that is suitable for use in this study can be found in section 1.3 in the previous chapter.

2.2.1 Evidence of Easy Credit for SOEs

Since one of my main goal in this chapter is to provide empirical prove that the input costs are different for firms with different ownership, I want to find some preliminary evidences to verify that the data set justifies my observations about SOEs' easy access to credit. My hypothesis is that SOEs and private firms pay different prices for loans and the per unit investment cost for SOEs is less than that for private firms.

To check for empirical evidence, I regress firms' capital to labor ratio on their private ownership dummy with other controls. I use three different model specifications, which are: (1) a model with a private dummy as the only independent variable; (2) a model with more controls including firms' added value, profit, and wage rate; and (3) a model with a firm fixed effect added to the previous model. The results are presented in Table 2.1. All three models yield negative estimates of coefficients on private ownership, which suggests SOEs' easy access to loans since each worker has less capital to work with in private firms.[5]

[5]Notice that the coefficient on the private ownership dummy in the firm fixed effect model is negative but not significant. This is probably because the model is identified by the changes within firms (instead of across firms), which are not an abundant case in my data set.

2.3 Theoretical Model

This section develops a theoretical model of market evolution when firms' ownership is subject to change. The model in this paper draws heavily on the fully dynamic workhorse industry evolution models by Hopenhayn (1992) and Ericson and Pakes (1995). In most models following this framework as well as my model, a firm makes a static decision on labor and realizes its current period profit through production, and then decides on whether to exit and then how much to invest. In detail, the model contains four structural components. The first is incumbent firms' static profit function that states how much money a firm earns given the state of the market. The second component describes the process of productivity evolution, in which the types of ownership (private or state-owned) affect the probability distribution of a firm's future productivity. Third, ownership is not fixed and can be changed by an exogenous process that reflects governments' market reform policies. The fourth and final component of the model depicts the behavior of potential entrants, which can be either private or state-owned firms. The following subsections discuss each of these components in greater detail.

2.3.1 Sequence of Actions

In this model, time is discrete and indexed by $t = 1, 2, 3, \ldots, \infty$. The firms competing in the market are called incumbents and indexed by $i = 1, 2, 3, \ldots, N_t$, where $N_t \in \mathbb{N}$ is the total number of incumbents in period t. An incumbent i's state in period t is represented by $s_{it} = (\omega_{it}, k_{it}, \rho_{it})$, where $\omega_{it} \in \Omega \subset \mathbb{R}$, $k_{it} \in \mathbb{K} \subset \mathbb{R}^+$, and $\rho_{it} \in \{0, 1\}$ are productivity, log real capital, and private ownership dummy, respectively, for this firm in this period.[6] $\rho_{it} = 1$ if firm i is privately owned at time t, and

[6]Note that I treat upper case and lower case letters differently in this paper. For example, lower case s_{it} represents an individual firm's state, while upper case letter S_t, which is defined in the following sentences, represents the state of the entire industry.

$\rho_{it} = 0$ if state-owned. Ω and $\mathbb{K}$ are the sets from which firms draw their productivity and log real capital, respectively. Following the conventions introduced above, the whole-industry state at each period t is denoted by $S_t = \{s_{1t}, s_{2t}, s_{3t}, \ldots, s_{N_t t}\}$, and $S_{-it} = \{s_{1t}, s_{2t}, \ldots, s_{i-1t}, s_{i+1t}, \ldots, s_{N_t t}\}$ represents the market state S_t disregarding the state of firm i, s_{it}. Because each firm's state s_{it} is drawn from a set $\mathbb{X} = \Omega \times \mathbb{K} \times \{0, 1\}$, the set of all possible industry states is denoted by $\mathbb{S} \subseteq \mathbb{X}^{\mathbb{N}}$.

At the beginning of period t, all incumbents engage in competition in the product market and simultaneously set their prices. This stage is static in the sense that firms have choices only involving their short-run production factors such as labor and material, but cannot alter dynamic variables such as capital, productivity, and ownership. From production, incumbent i realizes profit $\bar{\pi}_i(S_t)$ in period t.[7]

In the next stage, incumbent firms are confronted with exit and privatization decisions. The decision-making processes differ drastically between private firms and SOEs. In particular, a private incumbent observes an idiosyncratic scrap value ϕ_{it} that is centered at $\bar{\phi}$ and i.i.d across different firms and time, and decides on whether to exit given its own and all others' current state, S_t. On the other hand, even though SOEs also observe a scrap value, they do not have control upon exit. Instead, the government makes the exit decision for them according to their current states. If an incumbent firm, either state-owned or private, is exiting, it earns the current static profit plus scrap value. I use $\chi_{it} = 1$ to represent an exit decision, and $\chi_{it} = 0$ otherwise. In addition to exit, the government also decides on whether to privatize an SOE based on a probability that is a function of the SOE's and all other firms' state variables, S_t. If privatized, an SOE will appear to be a private firm in the following period, $\rho_{it+1} = 1$. Otherwise, it will remain an SOE, $\rho_{it+1} = 0$. I assume that, private

[7]Unlike most papers on this subject, I denote a firm's profit from static competition by $\bar{\pi}$, instead of π. The reason is that I reserve symbol π_{it} for the firm i's "net earnings" in period t. A firm's net earnings is the amount of profit $\bar{\pi}$ left after netting out its investment cost, capital adjustment cost, entry cost, and exit cost (if any).

firm will never be bought by governments because I find very few firms in my data set that changed their ownership type from private to state-owned. For those private firms that did become state-owned, I am not certain about the accuracy of such developments, and it is very likely that there was confusion about their ownership status during transition.

Upon remaining in competition, an incumbent has the option to invest in its own physical capital, k_{it}, to maximize the sum of its discounted expected future values. Because explaining firms' investment behavior is not the focus of my model, I assume a deterministic investment process, that a firm's physical capital in the following year is the sum of its current capital (after adjustment to depreciation) and new investment.[8]

Meanwhile, there is a group of potential entrants trying to make a decision about entry. To enter the market, an entrant has to pay a fixed entry cost κ and draw its initial state $s^e = (\omega^e, k^e, \rho^e)$ from a set $\mathbb{X}^e \subseteq \mathbb{X}$. Specifically, a potential entrant decides to enter if the discounted sum of its expected future values is higher than today's entry cost. I assume entry takes one period to realize due to a time-consuming preparation process. $\epsilon_{it} = 1$ means the potential entrant i decides to enter at time t, and $\epsilon_{it} = 0$ otherwise. With some minor assumptions, the number of firms entering a market at state S_t is a Poisson random variable with mean $M(S_t)$. At the very end of this period, continuing incumbent firms and new entrants constitute the market in the next period S_{t+1}, and the stages introduced above repeat all over again.

To summarize, the timing of events in period t is shown with the bullet points below. Additionally, a graphic representation of the game (a game tree) can be found in Figure 2·1.

1. Incumbent firms compete in the product market and realize profit $\bar{\pi}_i(S_t)$ through

[8] Notice that the physical capital mentioned here is not logged.

production.

2. Both private and state-owned incumbent firms privately observe an idiosyncratic scrap value ϕ_{it}.

   - Private Firms: decide whether to exit or continue as a private firm.
   - SOEs: obey governments' command to be either terminated (exit), or privatized, or left untouched.

3. If continuing, they make physical capital investment decision.

4. Potential entrants decide on whether to enter in the next period based on the current market state S_t.

5. Exiting takes place and the firms that are leaving receive their scrap values.

6. SOEs that are chosen to be privatized go through ownership transfer.

7. Continuing firms realize their investment outcomes, as well as their new draws of productivity.

8. New entrants enter, pay a fixed entry cost κ and draw their initial state, (ω^e, k^e, ρ^e), from the set $\mathbb{X}^e$.

In the following subsections, I describe these stages in detail in the context of my structural model.

2.3.2 Static Competition

How incumbents interact with each other in the production market is exactly same as my static competition model described in section 1.4. The model specification follows tightly from Peters, Roberts, Vuong, and Fryges (2015). The key of their method is that marginal cost does not depend on the level of total output a firm produces.

As mentioned in the previous chapter, the independence between marginal cost and total output simplifies the optimal pricing function, provides a tractable relationship between price and revenue, and in addition assists in the model's identification.

2.3.3 Transition of States

In this subsection, I present the modeling for state transition. There are three state variables for each firm: log real capital k_{it}, ownership ρ_{it}, and the structural productivity term ω_{it}.

Transition of Capital

The first state k_{it} evolves in a simple fashion. I assume investment in physical capital has a deterministic outcome, which implies that a firm i's future real capital is the sum of its current capital (adjusted by depreciation) and new investment without any uncertainties. I follow the convention to define capital letter K as actual level of capital ($K_{it} = exp(k_{it})$ for all firm i and all time t), and define I as actual level of investment ($I_{it} = exp(i_{it})$ for all firm i and all time t). Thus the capital evolution can be expressed by the following mathematical equations,

$$K_{it+1} = (1 - \delta)K_{it} + I_{it}, \tag{2.1}$$

where δ is depreciation rate.

To adjust a firm's physical capital stock, there are two costs involved: a capital adjustment cost and a total investment cost. I use $\tilde{c}(k_{it}, k_{it+1})$ to represent the capital adjustment cost and specify the following functional form,

$$\begin{aligned} \tilde{c}(k_{it}, k_{it+1}) &= C_a \left[\frac{I_{it}}{K_{it}}\right]^2 K_{it} \\ &= C_a \left[\frac{K_{it+1} - (1-\delta)K_{it}}{K_{it}}\right]^2 K_{it}, \end{aligned} \tag{2.2}$$

which is a way of saying that adjustment costs increase with (1) the amount of investment per unit of capital and (2) the total size of capital stock.[9] Total investment cost can be calculated by multiplying the amount of investment by per unit investment cost. As described in section 1.2.2, SOEs are preferred by the credit market because they are backed by governments and less risky for investors. Comparatively speaking, private firms are on their own and bare more risk, and probably find it more difficult to borrow the funds they need. In accordance with these circumstances, I expect to see a lower per unit investment cost for SOEs than for private firms. Therefore, I model per unit investment costs to be different for different types of firms and denote these costs for private and state-owned firms by C_K^P and C_K^S, respectively.

Having disparate per unit investment costs among firms with different ownership is an important and distinctive feature of my model. The effects of reforms on firms' productivity may well be overestimated if it is not incorporated into the model framework. In a typical dynamic model, a firm decides on the amount of capital goods to invest according to its observed current productivity in order to maximize the sum of a stream of discounted future values. Investment policies are going to be dramatically different for different types of firms if the unit prices that they have to pay are not the same. A firm facing a cheaper investment cost is less selective and able to choose a wider range of investment levels. Most of the time, it over-invests and purchases capital goods that are not very productive at the moment. Hence, it is predictable that its calculated productivities look unimpressive. However, these numbers do not reflect the firm's intrinsic efficiency because, if easy access to loans is not granted, it probably postpones such non-performing investments and focuses on improving the real productivity of its existing capital instead. Thus, the potential productivity of SOEs is not as deplorable as one might think, and the outstanding performance of private firms compared to SOEs may be exaggerated.

[9]This functional form strictly follows Xu (2008).

Another way to understand the importance of the difference in investment costs is to think about how we compare firms' productivities among two groups of firms with different characteristics. Usually, we divide the firms into groups according to the characteristics we want to investigate and compute an average measure of productivity within each group, which can be used to examine which group of firms is more efficient. In order to derive more accurate average numbers, we can weight productivities by firm size or total amount of capital in specific. Because of their cheaper investment costs, SOEs are inclined to grow bigger in size and therefore are given the heaviest weight when calculating average productivity. Therefore, the inefficiency in state-owned firms is overstated if we overlook the difference in input prices.

Transition of Ownership

The second state ρ_{it} evolves very differently for SOEs and private firms. As mentioned above, private firms are assumed to be private in the next period if not exiting, whereas SOEs can be privatized by governments. In other words, private firms cannot change their ownership, but SOEs can. There is actually another implicit state that specifies whether a firm exits the market. Exit decisions also are made in ways that are different for different types of firms. A private firm is capable of making its own exit decision χ_{it}, whereas an SOE has to follow governments' orders.

Notice that modeling governments as social welfare maximizers would be unpractical, because firstly I don't have a concrete idea about how Chinese governments measure social welfare, and secondly there are no relevant data to detect governments' concerns. Therefore, I model the government decision problem in reduced-form. Specifically, I model governments' actions as probabilities of exit and privatization that depend on firms' states. $F(\rho_{it+1} = 0 \mid \omega_{it}, k_{it})$ is the probability of SOE i not being selected for privatization in period t; $F(\rho_{it+1} = 1 \mid \omega_{it}, k_{it})$ is the probability of it being privatized. The probability of it being closed is $1 - F(\rho_{it+1} = 0 \mid \omega_{it}, k_{it}) - F(\rho_{it+1} = 1 \mid \omega_{it}, k_{it})$, which is saying that, if an SOE is neither a state-owned or private firm in the next period, it must have left the market.

Transition of Productivity

Finally, as presented in the end of section 1.4 of my previous chapter, a firm's total productivity state evolves as

$$\begin{aligned} \omega_{it+1} &= G(\omega_{it}, \rho_{it}) + \varepsilon_{it+1} \\ &= \alpha_0 + \alpha_1 \omega_{it} + \alpha_2 \omega_{it}^2 + \alpha_3 \omega_{it}^3 + \alpha_4 \rho_{it} + \varepsilon_{it+1}. \end{aligned} \tag{2.3}$$

The function $G(\cdot)$ is the conditional expectation of future productivity and ε_{it} is a zero mean stochastic shock. This functional form carries some very important information about productivity evolution. The details are discussed in section 1.4 of my first chapter. Interested readers are welcome to refer to previous chapter for further information.

To summarize, how each of these three state variables changes completely defines how a firm evolves. In turn, the evolution of market condition is also defined. One of the aspects that separates my model from others is that I allow one of the state variables, ownership ρ, to be altered by a party that is not a strategic player of the game, in this case governments.[10] As we will see in my empirical model in section 2.4, this treatment offers great opportunities to estimate complicated problems in a relatively simple fashion.

[10] I do not recognize governments as a player in the game because they do not interact with other firms strategically and their behaviors are completely summarized by a set of probabilities that are predetermined.

2.3.4 Incumbent's Maximization Problem

As we know from the related literature, the full set of dynamic Nash equilibria is unbounded and complex and thus I need to impose some restrictions in order to derive a tractable model. Following Ericson and Pakes (1995), I focus on anonymous, symmetric, and Markovian strategies. In particular, all firms adopt the same strategies, and they make decisions conditioning on their current state vector and private shocks. In period t, incumbent firm i makes exit, production, and investment decisions, collectively denoted by a_{it}. Thus, its strategy, denoted by $\sigma_i(S_t, \xi_{it})$, is a mapping from its states and shocks to actions,

$$\sigma_i : (S_t, \xi_{it}) \longrightarrow a_{it},$$

where ξ_{it} represents the firm's private information about its costs of exit and investment.

To present the value functions, there are more notations to be introduced. θ is a vector of payoff-relevant parameters and β is the discount factor. Recall that firms with different ownership have separate forms of value functions. The value function for a *private firm* i at time t is

$$\begin{aligned} V(\omega_{it}, k_{it}, \rho_{it} = 1, S_{-it}; \sigma, \theta, \phi_{it}, \xi_{it}) &= \bar{\pi}(\omega_{it}, k_{it}, \rho_{it}, S_{-it}) \\ &+ max\{V_c(\omega_{it}, k_{it}, \rho_{it}, \rho_{it+1} = 1, S_{-it}; \sigma, \theta, \xi_{it}), \phi_{it}\}, \quad (2.4) \end{aligned}$$

and the value function for a *state-owned enterprise (SOE)* i at time t is

$$\begin{aligned} V(\omega_{it}, &k_{it}, \rho_{it} = 0, S_{-it}; \sigma, \theta, \phi_{it}, \xi_{it}) = \bar{\pi}(\omega_{it}, k_{it}, \rho_{it}, S_{-it}) \\ &+F(\rho_{it+1} = 0 \mid \omega_{it}, k_{it}) \cdot V_c(\omega_{it}, k_{it}, \rho_{it}, \rho_{it+1} = 0, S_{-it}; \sigma, \theta, \xi_{it}) \\ &+F(\rho_{it+1} = 1 \mid \omega_{it}, k_{it}) \cdot V_c(\omega_{it}, k_{it}, \rho_{it}, \rho_{it+1} = 1, S_{-it}; \sigma, \theta, \xi_{it}) \\ &+(1 - F(\rho_{it+1} = 0 \mid \omega_{it}, k_{it}) - F(\rho_{it+1} = 1 \mid \omega_{it}, k_{it})) \cdot \phi_{it} \end{aligned} \tag{2.5}$$

where the *continuation value function* $V_c(\omega_{it}, k_{it}, \rho_{it}, \rho_{it+1}, S_{-it}; \sigma, \theta, \xi_{it})$ is defined as

$$\begin{aligned} &V_c(\omega_{it}, k_{it}, \rho_{it}, \rho_{it+1}, S_{-it}; \sigma, \theta, \xi_{it}) \\ &\quad = \underset{k_{it+1}}{\text{maximize}} \; \{- \left[\rho_{it+1} C_K^P + (1 - \rho_{it+1}) C_K^S\right] (exp(k_{it+1}) - (1 - \delta) exp(k_{it})) \\ &\qquad\qquad\qquad\qquad - \tilde{c}(k_{it}, k_{it+1}) \\ &\quad + \beta \int\limits_{\omega_{it+1}} \mathbb{E}_{S_{-it+1}, \phi_{it+1}, \xi_{it+1}} V(\omega_{it+1}, k_{it+1}, \rho_{it+1}, S_{-it+1}; \sigma, \theta, \phi_{it+1}, \xi_{it+1}) dG\}. \end{aligned} \tag{2.6}$$

In each period, both incumbent SOEs and private firms produce goods and realize profits $\bar{\pi}_{it}$ from selling them on the market. Then private firms decide on whether to exit (and then get scrap value ϕ_{it}) or continue as a private firm (and earn continuation value $V_c(\omega_{it}, k_{it}, \rho_{it}, \rho_{it+1} = 1, S_{-it}; \sigma, \theta, \xi_{it})$), while, on the other hand, SOEs undergo economic reform led by governments and may end up in one of the following three conditions: (1) no change (and obtain continuation value $V_c(\omega_{it}, k_{it}, \rho_{it}, \rho_{it+1} = 0, S_{-it}; \sigma, \theta, \xi_{it})$) with probability $F(\rho_{it+1} = 0 \mid \omega_{it}, k_{it})$, (2) privatized (and earn continuation value $V_c(\omega_{it}, k_{it}, \rho_{it}, \rho_{it+1} = 1, S_{-it}; \sigma, \theta, \xi_{it})$) with probability $F(\rho_{it+1} = 1 \mid \omega_{it}, k_{it})$, and (3) terminated (and only get scrap value ϕ_{it}) with probability $1 - F(\rho_{it+1} = 0 \mid \omega_{it}, k_{it}) - F(\rho_{it+1} = 1 \mid \omega_{it}, k_{it})$.

The continuation value $V_c(\omega_{it}, k_{it}, \rho_{it}, \rho_{it+1}, S_{-it}; \sigma, \theta, \xi_{it})$ is how much a firm is worth once it realizes its static profit and decides to continue in the market. Each firm chooses a physical investment level i_{it} (which is equivalent to choosing the next period physical capital level k_{it+1}, since capital evolves in a deterministic fashion) to maximize the sum of the following three components. The first component is negative total investment cost, which is the product of per unit investment cost, C_K^P or C_K^S depending on its ownership the following year, and total amount of investment $exp(k_{it+1}) - (1-\delta)exp(k_{it})$. The second component is the negative capital adjustment cost $\tilde{c}(k_{it}, k_{it+1})$ defined in equation (2.2). Lastly, I have the expected value of the firm starting from the next period, $V(\omega_{it+1}, k_{it+1}, \rho_{it+1}, S_{-it+1}; \sigma, \theta, \phi_{it+1}, \xi_{it+1})$, discounted by time preference β. It might not be obvious that continuation value depends on ownership at time t, ρ_{it}. Notice that calculating expected value in future involves integrating over all possible future productivities as shown in Equation (2.6), and a firm's future productivity depends not only on current productivity, but also current ownership type as indicated in Equation (2.3).

2.3.5 Entrant's Problem

The potential entrants are ex-ante identical. Upon entry, they draw their initial endowment of state $s^e = (\omega^e, k^e, \rho^e)$ from a distribution $\mathbb{X}^e \subseteq \mathbb{X}$. The value function for a potential entrant is

$$
\begin{aligned}
&V_e(S_t; \sigma, \theta) \\
&\qquad = \beta \mathbb{E}_{S_{-it+1}} \left[\int_{s^e} \mathbb{E}_{\xi_{it+1}} V(\omega^e, k^e, \rho^e, S_{-it+1}; \sigma, \theta, \xi_{it+1}) d\mathbb{X}^e \mid S_t \right]. \quad (2.7)
\end{aligned}
$$

This equation reflects the fact that a potential entrant's entry decision is made in period t but it only starts producing in the next period $t+1$. In other words, it takes one period for an entrant to prepare and become an incumbent once the entry decision has been made. Thus, an entrant's value is simply the expected value of an incumbent at time $t+1$ discounted by time preference β.

Since new entrants furthermore have to pay a fixed entry cost κ, a potential entrant is entering ($\epsilon_{it} = 1$) if

$$V_e(S_t; \sigma, \theta) \geq \kappa, \tag{2.8}$$

which is saying that the firm finds entering worth a try only if its expected value can cover the entry cost. In addition, following Xu (2008), the number of firms entering a market with state S_t can be modeled by a Poisson random variable with mean $M(S_t)$.[11] New entrants are important players in the market, in the sense that they create intense competition with incumbents, drive low-productivity firms out, and keep the technology used in the industry moving forward.

2.3.6 Equilibrium

As mentioned above, I restrict myself to anonymous, symmetric, and Markovian strategies in order to obtain a tractable equilibrium. I use σ without a subscript to represent a set of policy functions that describes all players' production, investment, entry, and exit behavior, $\sigma = \{\sigma_1, \sigma_2, \ldots, \sigma_{N_t}\}$. σ_i is the strategy of firm i and σ_{-i} is the strategy of all firms other than i, such that $\sigma = \{\sigma_i, \sigma_{-i}\}$. I follow the convention of using a star ($*$) symbol for equilibrium policies and therefore σ_i^* is the Symmetric Markov Perfect strategy for firm i. Following Ericson and Pakes (1995) and Weintraub, Benkard, and Van Roy (2007), a *Markov-perfect Nash equilibrium* (MPNE) requires

1. each firm's strategy profile to be optimal given the strategy profiles of all its competitors:

$$\begin{aligned} &V(\omega_{it}, k_{it}, \rho_{it}, S_{-it}; \sigma_i^*, \sigma_{-i}^*, \theta, \xi_{it}) \\ &\qquad \geq V(\omega_{it}, k_{it}, \rho_{it}, S_{-it}; \tilde{\sigma}_i, \sigma_{-i}^*, \theta, \xi_{it}), \end{aligned} \tag{2.9}$$

[11] Please consult Xu (2008) for a simple enter model that justifies the use of a Poisson random variable.

for all firms i, all private shocks ξ_{it}, all states $(\omega_{it}, k_{it}, \rho_{it}, S_{-it}) \in \mathbb{X}^{\mathbb{N}}$, and all possible alternative strategies $\tilde{\sigma}_i$, and

2. entrants to satisfy the zero profit condition such that,

$$V_e(S_t; \sigma, \theta) \leq \kappa \tag{2.10}$$

with equality if the mass of entrants $M(S_t) > 0$.

In the empirical exercise below, I note that taking integration over firms' private information does not affect the validity of the first MPNE condition (equation (2.9)),[12] so that

$$V(\omega_{it}, k_{it}, \rho_{it}, S_{-it}; \sigma_i^*, \sigma_{-i}^*, \theta) \geq V(\omega_{it}, k_{it}, \rho_{it}, S_{-it}; \tilde{\sigma}_i, \sigma_{-i}^*, \theta) \tag{2.11}$$

where $V(\omega_{it}, k_{it}, \rho_{it}, S_{-it}; \sigma, \theta) = \mathbb{E}_{\xi_{it}} V(\omega_{it}, k_{it}, \rho_{it}, S_{-it}; \sigma, \theta, \xi_{it})$.[13] This will be the condition used in the empirical model to identify the firms' dynamic variables. Working with the expected equilibrium condition (equation (2.11)) spares us from the extra hurdle of making sure the equilibrium conditions are satisfied for all possible private shocks ξ_{it} when searching for underlying parameter values. Finally, as discussed in Doraszelski and Satterthwaite (2010), there exists at least one pure strategy equilibrium by introducing private information over the discrete actions in settings similar to the one presented here, as long as the best response curves are continuous. However, I also notice that there is no guarantee on the uniqueness of equilibrium. These issues are discussed in detail along with my empirical model in section 2.4.

[12] I adopt this trick from Ryan (2012).

[13] Notice that this expected value function is defined in exactly the same way as the value function in Bajari, Benkard, and Levin (2007) (BBL hereafter), but equation (2.4) and (2.5) are not. The difference is actually not about the obvious fact that the value function defined in BBL is written as the summation of an infinite stream of payoffs instead of a Bellman equation. In fact, the real difference is that the value functions in BBL do not depend on the current private shock ξ_{it} while mine (equations (2.4) and (2.5)) do. Thus, if we take the one extra step of taking expectations over current private shocks ξ_{it}, we have a value function that is exactly same as in BBL. The reason why I keep ξ_{it} as one of the arguments in equations (2.4) and (2.5) is that those value functions are in Bellman equation form, which looks unconventional if I integrate over ξ_{it}.

2.4 Empirical Strategy

To estimate the model, we need to overcome two fundamental problems. First, estimating a dynamic model such as this one can be very computationally demanding. For example, to use maximum-likelihood approaches, it is necessary for us to compute an equilibrium for every guess of the parameter vector, which can be unpractical and may take years for a regular computer to run the program (Benkard (2004)). Second, multiple equilibria may exist since firms strategically interact with each other. In particular, each firm's actions have influence over the aggregate market condition (summarized by a price index PI_t), based on which other firms decide what to do. The challenges of having multiple equilibria are twofold: (1) it is necessary to compute all possible equilibria, and (2) it is difficult to define which equilibrium is played in the data (Bajari, Hong, and Ryan (2010)).

To circumvent these two problems, I adopt the empirical method proposed by Bajari, Benkard, and Levin (2007; BBL). Briefly, BBL is a two-stage estimation process, of which the first stage flexibly solves for agents' policy functions and state transitions, and the second stage recovers the dynamic parameters from the equilibrium conditions. The intuition of BBL is straightforward and easy to understand. The actions of agents, which are assumed to be generated from equilibrium policies, are observable to us from the data. Therefore, estimating such actions using reduced-form regressions with flexible functional forms recovers their optimal policies no matter what policies they use. Then I can use the model's equilibrium conditions to find the parameters of the underlying model that justify the estimated policies in the first step.

Specifically in this application, I start by estimating the equilibrium policy functions governing entry, exit, and investment, (σ_i), along with governments' privatization and termination decisions ($F(\rho_{it+1} \mid \omega_{it}, k_{it})$), and the product market profit function ($\bar{\pi}_{it}$). The key to achieving an accurate estimation in this step is to impose as little structure as possible on the functions used. I mechanically characterize what firms do given their state vectors. In other words, I carry out reduced-form regressions of firms' actions on their states with functional forms that are made as flexible as possible. In the second step, I impose the definition of MPNE in equation (2.11) on the recovered policy functions. Given the policies estimated in the previous step, it is possible to construct the expected value function of using an optimal strategy, $V(\omega_{it}, k_{it}, \rho_{it}, S_{-it}; \sigma_i^*, \sigma_{-i}^*, \theta)$. Similarly, I can also find the expected value of using any alternative strategies, $V(\omega_{it}, k_{it}, \rho_{it}, S_{-it}; \tilde{\sigma}_i, \sigma_{-i}^*, \theta)$. The MPNE condition holds if the value of using the equilibrium strategy is larger than that of using other alternatives. Thus I can calculate a penalty value whenever the equilibrium condition is violated for a sufficiently rich set of alternative strategies and states. Ultimately, the parameters θ that minimize the accumulated penalties are the optimal ones that make sense of the estimated policies.

As mentioned above, BBL is able to solve two common problems associated with this type of estimation. Once I have presented more details about my specific estimation process, we can see how BBL works to deal with these problems. One of the greatest advantages of this approach is that simple regressions are much easier to run than computing the equilibrium using the nested fixed-point maximum likelihood algorithm (Rust (1988)), which can be time consuming for a model like this.[14] Furthermore, being able to estimate firms' policies with simple regressions is also the reason why BBL can deal with the multiple equilibria problem. More than one equilibrium may exist, and firms in the data set are functioning according to one or another of them. However, the optimal policies estimated using reduced-form regres-

[14] In fact, even if I adopt BBL, the computational burden can still be insuperable. For example, it may be necessary in some models to forward-simulate value functions for each set of parameters θ, and searching over each possible θ can be very time consuming. Luckily, in this application, I am able to linearize the profit function such that forward simulation needs to be done only once. Details are presented in section 2.4.2

sions in the first stage must be the equilibrium policies that are in fact followed by the firms. Therefore, I actually know which equilibrium is played and can successfully sidestep the need to compute all possible equilibria.[15]

2.4.1 Step One: Estimation of Static Profits And Policy Functions

In the first stage, I estimate the static profits that accrue to firms in each period, investigate on what criteria governments' privatization and termination decisions are based, and characterize firms' entry, exit, and investment behavior conditional on their state variables.

Static Profits and Productivity Evolution

I start my estimation with the static profit function and productivity evolution process. Since the static competition part of my dynamic model is identical to the model used in my first chapter, I am able to adopt the same estimation strategy, as well as its results. As mentioned earlier, it is important to explain why I estimate productivity evolution together with the profit function, rather than working on them separately as for all other state variables. The short answer is that, unlike ownership and capital level, productivity is unobservable to econometricians. More specifically, the evolutions of ownership and capital, which are observed state variables, can be estimated by reduced-form regressions, but firms' productivity evolution function (equation (2.3)) must be estimated with their revenue function, which implicitly defines unobserved productivities using firms' observed data. To summarize, the key

[15]To make sure the multiple equilibria issue is properly dealt with, we often have to make some other necessary assumptions. For example, Ryan (2012) assumes that the same equilibrium is played in all markets. This is to prevent the possibility that different markets converge into different equilibria, and to ensure that the estimated policies derived from the pulled dataset are able to accurately characterize the equilibrium. In fact, it may not even be possible to estimate a distinct set of policies for each market since there are not sufficient data available. However, in particular for this application, there is only one monopolistically competitive market rather than several different ones in different locations, and the estimated policy functions surely can characterize firms' behaviors if I make the same assumption as in Ryan (2012).

parameters to be estimated in this subsection are the parameters of cost function (β_k and β_ρ), the parameters of productivity evolution ($\alpha_0, \alpha_1, \ldots, \alpha_4$), and the elasticity of demand (η). All the estimation details are presented in section 1.5 of the previous chapter.

Privatization and Exit Policy Function

As mentioned in my theoretical model, private firms decide by themselves whether to exit, but SOEs take privatization and termination orders from governments. While private firms are not allowed to change their ownership type, SOEs can be transformed into private firms if selected by governments to go through privatization. Both private firms and SOEs can exit the market, but they have to go through two different channels; private firms exit because they are not profitable, but SOEs stop operating because governments believe it is better to terminate them. In the rest of this subsection, I consider the exit and privatization policies of these two types of firms separately, beginning with private firms.

I first pull all private observations together and then define an exit dummy variable χ_{it}, which equals 1 if a private firm i is present in period t but disappears from the dataset at time $t+1$. The exit decision by private firms is modeled by a logistic regression,

$$\text{logit}(F(\chi_{it} \mid \omega_{it}, k_{it}, S_{-it})) = \beta_0^e + \beta_1^e \omega_{it} + \beta_2^e k_{it} + \beta_3^e PI_t. \tag{2.12}$$

Notice that I use PI_t to control for current market conditions so that I do not have to know all other firms' states. In the results section below, I also adopt other model specifications for comparison. Once I obtain a set of estimates, a probability of exit can be calculated for each firm given the firm's state vector.

For SOEs, I collect all state-owned observations and define a categorical variable

Y_{it} which equals 1 if SOE i becomes privately owned in period $t+1$, equals 2 if it disappears in period $t+1$, and equals 3 if it is still an SOE in the next period. Hence, the definition of variable Y_{it} can be summarized as,

- $Y_{it} = 1$ if privatized,
- $Y_{it} = 2$ if terminated, and
- $Y_{it} = 3$ if unchanged.

I use a multinomial logistic regression to characterize governments' decisions,

$$\begin{aligned} log\frac{Pr(Y_{it}=1)}{Pr(Y_{it}=3)} &= \beta_0^p + \beta_1^p\omega_{it} + \beta_2^p k_{it} + \beta_3^p PI_t \\ log\frac{Pr(Y_{it}=2)}{Pr(Y_{it}=3)} &= \beta_0^t + \beta_1^t\omega_{it} + \beta_2^t k_{it} + \beta_3^t PI_t, \end{aligned} \tag{2.13}$$

where $Pr(\cdot)$ represents the probability of the event in parentheses. In this regression, I treat unchanged SOEs as my reference group to which the other two groups are compare. Later in the results section, the estimates of several alternative specifications are also presented for the purpose of comparison.

Investment Policy Function

I would like to estimate firms' investment policy using a function that is as flexible as possible. In order to do that, I regress the log of firms' capital in the next period on a third-order polynomial of their current states,

$$\begin{aligned} k_{it+1} = \beta_0^k &+ \beta_1^k k_{it} + \beta_2^k\omega_{it} + \beta_3^k\rho_{it} + \beta_4^k PI_t + \beta_5^k k_{it}^2 + \beta_6^k\omega_{it}^2 \\ &+ \beta_7^k k_{it}\omega_{it} + \beta_8^k k_{it}\rho_{it} + \beta_9^k\omega_{it}\rho_{it} + \beta_{10}^k k_{it}^3 + \beta_{11}^k\omega_{it}^3 \\ &+ \beta_{12}^k k_{it}^2\rho_{it} + \beta_{13}^k k_{it}\rho_{it}^2 + \beta_{14}^k k_{it}^2\rho_{it} + \beta_{15}^k\omega_{it}^2\rho_{it} + \nu_{it} \end{aligned} \tag{2.14}$$

I cannot include all possible terms in the regression because the regressors may form a deficient matrix that could affect the accuracy of my estimates. Different versions of specification are tested and their results are also presented in a later section.[16] In fact, as will be discussed in a moment, it is important for the model to contain up to at least the third-order terms in this application, because this ensures that the growth rate (or the derivative) of the regression line decreases in relation to firms' capital level, such that a simulated firm could never be equipped with an infinite amount of capital.

Entry Policy Function

In theory, a potential entrant makes its entry decision according to the current market state S_t. However, I simplify this process in my empirical model because (1) there are only a few different market states available (only 10 in this case) for me to find accurate estimates, and (2) I believe that most entries during my sample years in China are policy driven instead of market driven.[17] Hence, even though I still assume that the mass of entrants is a Poission random variable, it is invariant to different market states. The mean and variance are estimated by the average number of entrants calculated from my data set.[18]

Upon entry, a new entrant draws its initial endowment of state $s^e = (\omega^e, k^e, \rho^e)$ from a distribution $\mathbb{X}^e \subseteq \mathbb{X}$. To estimate the distribution $\mathbb{X}^e$, I first calculate the percentages of state-owned entrants in each sample year, and the overall average is the estimated probability of an entrant being state-owned. The distribution of initial capital is estimated separately for SOEs and private firms. To achieve maximum

[16]In the empirical results section, I adopt several different models for comparison. I also replace the dependent variable with the level of investment and the investment per unit of capital. In addition, I test a much simpler linear model. Furthermore, any combination of these changes should also be anticipated.

[17]At the end of 1997s, there were mass layoffs, which created a rapid rise in the unemployment rate. Most unemployed workers had not saved enough for retirement and had to find alternative sources of income. Opening a small business became one of the most viable options, and sometimes the only option. Therefore, many new businesses during that period were actually not carefully planned and their openings had little to do with the market state at that moment.

[18]As a reminder, the mean of a Poisson distribution is equal to its variance.

flexibility, I adopt a nonparametric method. In particular, I apply a kernel density estimation with a normal kernel smoothing function and optimal bandwidth for normal density. Likewise, the distribution of entrants' productivity is estimated in a very similar way to that of initial capital.

2.4.2 Step Two: Estimation of Structural Parameters

In the second step, I try to find the values of the dynamic parameters that make sense of the policy functions found in the previous step. Theoretically, the actual strategies employed by participating firms must be the ones played in the equilibrium of my model, which generate the highest present values than any other alternatives. Thus I can impose optimality conditions defined in MPNE on these recovered strategies to estimate the dynamic parameters.

Estimating Value Function

I define π_{it} to be firm i's net earnings in period t.[19] A firm's net earnings in period t equals its static profit $\bar{\pi}_{it}$ netting out its investment cost, capital adjustment cost, entry cost, and exit cost if there are any in this period. Notice that, unlike static profit $\bar{\pi}_{it}$, net earnings π_{it} depends on firms' strategy profile, dynamic parameters and private shocks. Mathematically, for an incumbent i,

$$\begin{aligned}\pi_{it} = \pi(\omega_{it}, k_{it}, \rho_{it}, S_{-it}; \sigma, \theta, \xi_{it}) &= \bar{\pi}(\omega_{it}, k_{it}, \rho_{it}, S_{-it}) \\ &- \left[\rho_{it+1} C_K^P + (1-\rho_{it+1}) C_K^S\right] (exp(i_{it})) - C_a \left[\frac{exp(i_{it})}{exp(k_{it})}\right]^2 exp(k_{it}) \\ &+ \chi_{it}\phi_{it}, \quad (2.15)\end{aligned}$$

where i_{it}, χ_{it} and ρ_{it+1} are generated from investment policy, exit policy, and government privatization and termination policy, which depend on firms' current states and

[19] Ryan (2012) refers to net earnings as a per-period payoff function.

the state of the entire market. Then a firm's expected value function (equations (2.4) and (2.5) integrated over current private shock ξ_{it}) can be rewritten as,

$$V(\omega_{it}, k_{it}, \rho_{it}, S_{-it}; \sigma, \theta) = \mathbb{E}\left[\sum_{\iota=t}^{\infty} \beta^{\iota-t}\pi(\omega_{i\iota}, k_{i\iota}, \rho_{i\iota}, S_{-i\iota}; \sigma, \theta, \xi_{i\iota}) \mid S_t\right], \tag{2.16}$$

where the expectation is over current and future values of private shocks $\xi_{i\iota}$ and states S_ι.[20]

I now show how forward simulation can be used to estimate firms' expected value functions for any given strategy profiles σ (including the equilibrium profile σ^* and any alternatives $\tilde{\sigma}$) and any given parameters $\theta = \{C_K^P, C_K^S, C_a, \bar{\phi}\} \in \Theta$. Following Bajari, Benkard, and Levin (2007), the simulation steps can be summarized as: [21]

1. Specify the selected starting state of the market $S_t = S$ and draw private shocks ξ_{it} for each firm i.

2. Calculate static profit $\bar{\pi}(\omega_{it}, k_{it}, \rho_{it}, S_{-it})$ for each firm i.

3. Calculate each firm's actions a_{it} (which include investment i, privatization ρ, and exit χ) according to its own policies $\sigma_i(S_t, \xi_{it})$ and governments' privatization and termination policies derived in the first stage.

4. Given the actions calculated from the previous step, update each firm's states for the next period, $(\omega_{it+1}, k_{it+1}, \rho_{it+1})$.

5. Draw the mass of entrants M from the estimated Poisson distribution. Each

[20] Note that this definition of the value function is exactly same as the one in BBL, not only because it is written as the summation of an infinite stream of payoffs, but also because it is integrated over current private shocks ξ_{it}. Furthermore, I only have to write one value function for both private firms and SOEs, where in equations (2.4) and (2.5) I have two different value functions for them. The reason behind this is that, if value functions are written as the summation of a stream of net earnings instead of in a Bellman equation form, the differences between the two types of firms are fully captured by their ownership dummy ρ_{it+1} and exit decision χ_{it}.

[21] The procedure is in fact a bit different from the one in BBL, mainly because I have firms' exit and entry actions explicitly written out.

new entrant realizes its initial state $s^e = (\omega^e, k^e, \rho^e)$ drawn from the estimated distribution $\mathbb{X}^e$.

6. The market state of the next period, S_{t+1}, is updated according to the information on incumbents' new states and incoming new entrants.

7. Repeat steps 1 to 6 with new market state S_{t+1} for T periods. The value function for each firm can be calculated as the sum of all discounted net earnings in these T periods.

In fact, the discounted sum of a firm's net earnings per period gives us just one possible value of this firm. Small differences in private shocks may change its value to some extent. Hence, I do the same steps above for N_s times, and take the average as an estimate of $V(\omega_{it}, k_{it}, \rho_{it}, S_{-it}; \sigma, \theta)$, which I denote as $\hat{V}(\omega_{it}, k_{it}, \rho_{it}, S_{-it}; \sigma, \theta)$.[22] In practice, the number of simulations N_s is set to 100. The starting state S is chosen to be the market condition of China's Electronic and Telecommunications Industry in 1997, the first year of my sample period. The number of periods simulated forward, T, is set to 300. Most papers that adopt a similar strategy do not simulate more than 300 periods into the future because (1) most firms do not survive that many years, and (2) the discount factor for a year more than 300 periods away from now is so small that the net earning in that period is almost irrelevant to us today.[23] I also follow Cooper and Haltiwanger (2006) to set an annual discounting rate β at 0.95 and an annual rate of depreciation δ at 0.06.

However, the forward simulation procedure introduced above is much more difficult to perform than to explain. As will be shown in later subsections, in order to find the optimal parameters θ^* using equilibrium conditions, I have to implement a procedure that scans over many different parameter values. For each set of these

[22]Note that this value function does not depend on private shock ξ_{it} because it is the expected value function over private shock.

[23]Ryan (2012) simulates 200 periods.

parameters, I have to repeat forward simulations for all states even if the same simulation draws are used throughout. Therefore, finding the optimal set of parameters can be a time-consuming process. Luckily, the net earnings can be linearized to reduce necessary computations and the details are the focus of the next subsection.

Exploiting Linearity

The net earnings function (equation (2.15)) can be written as a linear function in parameters θ,

$$\pi_{it} = \pi(\omega_{it}, k_{it}, \rho_{it}, S_{-it}; \sigma, \theta, \xi_{it}) = [\bar{\pi}_{it}, \zeta_{it}] \cdot [1, \theta]', \tag{2.17}$$

where

$$\zeta_{it} = \left[-exp(i_{it}) \cdot \rho_{it+1}, -exp(i_{it}) \cdot (1 - \rho_{it+1}), -\left[\frac{exp(i_{it})}{exp(k_{it})} \right]^2 exp(k_{it}), \chi_{it} \right]$$
$$\theta = \left[C_K^P, C_K^S, C_a, \bar{\phi} \right].$$

Then the value function defined in equation (2.16) can be further transformed into,

$$\begin{aligned} V(\omega_{it}, k_{it}, \rho_{it}, S_{-it}; \sigma, \theta) &= \mathbb{E} \left[\sum_{\iota=t}^{\infty} \beta^{\iota-t} [\bar{\pi}_{it}, \zeta_{it}] \mid S_t \right] \cdot [1, \theta]' \\ &= W_{it} \cdot [1, \theta]', \end{aligned} \tag{2.18}$$

where I define $W_{it} = W(\omega_{it}, k_{it}, \rho_{it}, S_{-it}; \sigma) = \mathbb{E} \left[\sum_{\iota=t}^{\infty} \beta^{\iota-t} [\bar{\pi}_{it}, \zeta_{it}] \mid S_t \right]$[24]. Again, the expectation in the equation above is over current and future values of private shocks $\xi_{i\iota}$ and states S_ι.

What makes this form of value function much easier to work with is that W_{it} is independent of unknown parameters θ. In the next subsection, I explain in detail the need to forward-simulate value functions for each set of parameters θ when trying to

[24] W_{it} is a five dimensional vector, $W_{it} = \{W_{it}^1, W_{it}^2, \ldots, W_{it}^5\}$.

find the estimates θ^*. If the value function is in fact linear in unknown parameters as in equation (2.18), we only have to forward-simulate once to get W_{it}, and the value functions for any set of parameters θ are easily calculated by multiplying θ by W_{it}.

Imposing Equilibrium Conditions

Now I make use of the model's equilibrium conditions (equation (2.11)) to find the underlying model parameters θ^*. Recall that a strategy profile σ^* constitutes a *Markov-perfect Nash equilibrium* if and only if,

$$V(\omega_{it}, k_{it}, \rho_{it}, S_{-it}; \sigma_i^*, \sigma_{-i}^*, \theta) \geq V(\omega_{it}, k_{it}, \rho_{it}, S_{-it}; \tilde{\sigma}_i, \sigma_{-i}^*, \theta),$$

for all firms i, all states $(\omega_{it}, k_{it}, \rho_{it}, S_{-it}) \in \mathbb{X}^{\mathbb{N}}$, and all possible alternative strategies $\tilde{\sigma}_i$. Define

$$g(\ell; \theta) = V(\omega_{it}, k_{it}, \rho_{it}, S_{-it}; \sigma_i^*, \sigma_{-i}^*, \theta) - V(\omega_{it}, k_{it}, \rho_{it}, S_{-it}; \tilde{\sigma}_i, \sigma_{-i}^*, \theta), \tag{2.19}$$

where $\ell \in \mathbb{L}$ indexes a particular combination of $(i, (\omega_{it}, k_{it}, \rho_{it}, S_{-it}), \tilde{\sigma}_i)$. Notice that the function $g(\ell; \theta)$ must be positive if the equilibrium condition is to hold for the specified $\ell = (i, (\omega_{it}, k_{it}, \rho_{it}, S_{-it}), \tilde{\sigma}_i)$; otherwise, the firm i with states $(\omega_{it}, k_{it}, \rho_{it})$ violates the optimal condition because playing the alternative strategy $\tilde{\sigma}_i$ in the market $S_t = (\omega_{it}, k_{it}, \rho_{it}, S_{-it})$ is in fact better than equilibrium strategy σ_i^*. With the procedure presented in section 2.4.2, function $g(\ell; \theta)$ can be estimated by forward-simulating the value functions of firm i using strategy σ_i^* and $\tilde{\sigma}_i$,

$$\hat{g}(\ell; \theta) = \hat{V}(\omega_{it}, k_{it}, \rho_{it}, S_{-it}; \sigma_i^*, \sigma_{-i}^*, \theta) - \hat{V}(\omega_{it}, k_{it}, \rho_{it}, S_{-it}; \tilde{\sigma}_i, \sigma_{-i}^*, \theta). \tag{2.20}$$

I draw $\{\ell_1, \ell_2, \ldots, \ell_{N_l}\}$ from $\mathbb{L}^{N_l}$, where N_l stands for the total number of equilibrium conditions I consider, and minimize a measure of average penalties resulting from violating equilibrium conditions to get the parameters θ^*,

$$\theta^* = \underset{\theta \in \Theta}{\text{argmin}} \ \frac{1}{N_l} \sum_{k=1}^{N_l} (min\{\hat{g}(\ell_k;\theta), 0\})^2. \tag{2.21}$$

Please see Bajari, Benkard, and Levin (2007) for the prerequisite assumptions ensuring the existence of a minimizer to the problem above, and they also specify the sufficient conditions for this estimator to be consistent and asymptotically normal.

In practice, there are almost infinite number of different ways to draw $\{\ell_1, \ell_2, \ldots, \ell_{N_l}\}$. Specifically for this application, I first take all firms in 1997 as well as their states to be my draws of firms and states. I then generate a set of alternative strategies by adding an error term drawn from a standard normal distribution to my estimated investment and exit policy functions. For each combination of firm and state, I randomly select 10 alternative strategies for it. Thus the total number of selected combinations N_l is 10 times the number of observations in 1997.

Let us not revisit the linearity property of the firms' value function and discuss its advantages. I substitute the linearized value function equation (2.18) into equation (2.19) to get,

$$g(\ell;\theta) = \left[W(\omega_{it}, k_{it}, \rho_{it}, S_{-it}; \sigma_i^*, \sigma_{-i}^*) - W(\omega_{it}, k_{it}, \rho_{it}, S_{-it}; \tilde{\sigma}_i, \sigma_{-i}^*)\right] \cdot [1, \theta]'. \tag{2.22}$$

As can be seen from this equation, I do not have to recompute separate outcome paths for each different set of parameters. No matter what value θ takes, the term

$$W(\omega_{it}, k_{it}, \rho_{it}, S_{-it}; \sigma_i^*, \sigma_{-i}^*) - W(\omega_{it}, k_{it}, \rho_{it}, S_{-it}; \tilde{\sigma}_i, \sigma_{-i}^*)$$

does not change. Therefore I save considerable computational time by simulating only once to get $W(\omega_{it}, k_{it}, \rho_{it}, S_{-it}; \sigma_i^*, \sigma_{-i}^*) - W(\omega_{it}, k_{it}, \rho_{it}, S_{-it}; \tilde{\sigma}_i, \sigma_{-i}^*)$ for all N_l

combinations of $(i, (\omega_{it}, k_{it}, \rho_{it}, S_{-it}), \tilde{\sigma}_i)$. Then searching for optimal parameter values θ^* does not involve any forward simulations.

Unfortunately, even running the same simulation twice may give us different firm behaviors, different market evolutions, and in turn different estimates of the parameters. Therefore, simply solving equation (2.21) once may not result in the best estimates. Instead, I solve equation (2.21) multiple times and report the empirical distributions of all those estimates along with some statistics of the distribution, for example, the mean, the standard error, and the quantiles.

This concludes the discussion of my empirical model. To summarize, I present in this section a two-step empirical method to estimate the parameters of my theoretical model. In the first step, I estimate firms' static profit, productivity evolution, entry and exit decisions, investment behavior, and governments' privatization and termination decisions. In the second step, I find the optimal dynamic parameters by minimizing the penalties of firms violating equilibrium conditions. The results of my estimation are discussed in the next section.

2.5 Empirical Results

In this section, I present the estimates of my model. I start with the results of my first-stage estimation, including the estimated static profit function and firms' policy functions. For each policy, I adopt several different models and the estimates are compared with each other in order to find the most reasonable ones to use in the second stage of the estimation. After that, I discuss my estimates of the dynamic parameters from the second stage.

2.5.1 Static Profit and Productivity Evolution

The key parameters to be estimated for the static profit function $\bar{\pi}$ are fixed time effects $\gamma_1, \gamma_2, \ldots, \gamma_{10}$, elasticity of demand η, cost elasticity of capital β_k, and the difference in marginal costs between private and state-owned firms β_ρ. To characterize productivity evolution (equation (2.3)), I estimate its parameters $\alpha_0, \alpha_1, \ldots, \alpha_4$. As mentioned earlier, the static competition model, as well as its estimation and results, are identical to the one used in my previous chapter. Therefore, all results have been presented in Table 1.6, 1.7, and 1.8, as well as in Figure 1·4, 1·5, and 1·3. The detailed discussion of the results can be found in section 1.6.

2.5.2 Private Firms' Exit Decisions

Private firms decide whether to exit based on their current states (equation (2.12)). Their exit policy function can be estimated with logistic regressions, and I use three models for this exercise. Real capital and productivity enter the policy function linearly in model 1. Model 2 adds a market price index PI_t. I also include second- and third-order terms in model 3 for a more flexible specification. I report my estimates of all three models in Table 2.2 and the numbers are very similar among them.

We have negative coefficients on real capital, indicating that the larger a firm is, the more competitive it becomes and the less likely it exits. The odds ratio of one more unit of k_{it} is 0.882 ($e^{-0.125}$) in Models 1 and 2, and 0.840 ($e^{-0.174}$) in Model 3. The coefficients on productivity also are negative, indicating that more efficient firms are more likely to survive the competition and stay in the industry. This result conforms to our common sense and is quite easy to interpret. The odds ratio of one more unit of ω_{it} is 0.015 ($e^{-4.188}$ and $e^{-4.187}$) in Models 1 and 2, and 0.001 ($e^{-6.532}$) in Model 3. In addition, it seems like exit decisions are mainly based on firms' own states, but not the state of the entire market, as the coefficient on the market price index is not significant.

For all the models, I perform a coefficient test, which is in fact an F test on the null hypothesis that all coefficients are jointly zero except for the intercept term. The P-values reported below the test statistics indicate that at least one coefficient in each model is non-zero. In addition, a likelihood-ratio test answers the question of whether the chosen model fits significantly better than a model with only a constant. The results again are significant in all my models, indicating that they have some power to explain the underlying data. In the second stage where I simulate firms' value functions, I use the results from Model 1, because it is simple, captures all the features of the data, and gives us good results for the dynamic parameters.

2.5.3 SOEs' Exit and Privatization Decisions

In this section, I turn my attention to SOEs. I would like to know how governments decide on the destiny of SOEs based on their states. I estimate the parameters in equation (2.13), and report them in Table 2.3. There are two regressors, k_{it} and ω_{it}, in Model 1. I add price index PI_t in Model 2. In the last model, I also include squared terms as regressors.

First of all, all three models show positive effects of productivity on the chances of privatization but negative effects on termination. This indicates that, for two SOEs of the same size, the more productive one is more likely to be privatized, and the less efficient one has a higher chance of being terminated. These results reflect a very important principle based on which governments make reform decisions during China's transformation of the economic system. Efficient SOEs are more likely to survive once they are no longer receiving governments' subsidies, and, therefore, privatizing them becomes a sound strategy. In contrast, inefficient SOEs struggle even with governments on their back, and they are unlikely to do well once privatized. Therefore, closing those inefficient ones is the most reasonable action. In addition, the numbers also tell us that, for SOEs with modest productivity, there is no special treatment applied. In the second-stage estimation, I use Model 2 because (1) the price index PI_t has significant effects and (2) higher order terms are mostly insignificant. In this model, for an average SOE (which has log real capital of 9.589 and productivity of 0.040), a 1% increase in productivity raises the probability of privatization by 0.004 percentage points and lowers the probability of termination by 0.01 percentage points.[25]

In both Models 1 and 2, we can see clearly that the larger a SOE is, the lower the chance of it being privatized or terminated. In fact, Model 3 delivers the same information but may be less obvious because I have higher order terms in the regressions. Even though the coefficient on capital in the first regression of Model 3 is positive, the marginal effect of log real capital on the chances of privatization is still negative because of the negative coefficient on capital squared. For an average SOE with a capital level of 9.589, the marginal effect calculated is -0.475, which is comparable to that in Models 1 and 2.[26] As mentioned before, governments' reforms follow a guideline that can be summarized as "grasp the large and let go of the small." In accord with the literal meaning, small SOEs are often at the top of the list when governments consider which firms to privatize or terminate. My results confirm this policy and support it with meaningful numbers. The estimates of Model 2 suggest that, for an average SOE,[27] a one unit increase in log real capital (which is about 25.093 thousand RMB in terms of real capital) decreases the probability of privatization by 0.683 percentage points and reduces that of termination by 0.495 percentage points.[28]

Unlike private firms' exit choices, macro-level market conditions (summarized by

[25]The industry price index PI_t used to calculate these probabilities is the average price index across my sample periods. The probability of privatization changes from 3.177% to 3.181%, and the probability of termination changes from 5.797% to 5.787%, in response to a 1% increase in productivity.

[26]There is no such problem in the second regression of Model 3 because the higher order terms are all insignificant.

[27]Recall that an average SOE has log real capital of 9.589 and productivity of 0.040.

[28]The industry price index PI_t used to calculate these probabilities is the average price index across my sample periods. The probability of privatization changes from 3.177% to 2.494%, and the probability of termination changes from 5.797% to 5.302%, in response to a one unit increase in log real capital.

the industry price indexes) play a significant role in governments' decisions on SOE reform. From equation (1.9), we know that my definition of the price index, PI_t, is a complicated aggregation of the conditions of the firms in the market. Two dominant factors affecting price indexes are the number of firms and their productivities. In particular, price indexes increase with both the number of firms in the industry and each existing firm's productivity level.[29] Therefore a large PI_t can be associated with a market that appears to be in a relatively healthy condition. The negative coefficient on PI_t tells us that governments have less incentive to conduct dramatic reforms in a market that is functioning well. In contrast, governments tend to pursue reforms more urgently when an economy is in trouble. Finally, the results of likelihood-ratio tests confirm that all my models explain the data better than a constant model.

2.5.4 Investment Policy

Investment decisions are estimated by regressing different measures of investment level on firms' states. I design three groups of regressions, each with a different dependent variable. In particular, the dependent variables chosen are (1) log real capital level in next year, (2) investment level (not logged), and (3) investment capital ratio (not logged).

Model 1 to Model 4 are specifications belonging to the first group and their results are presented in Table 2.4. In Model 1, firms' log real capital, productivity, and private ownership dummy enter the regression function linearly. We see from the estimates that firms' capital levels are persistent over time with a coefficient on k_{it} of 0.902. The coefficient of ω_{it} tells us that a one percentage point increase in productivity raises the real capital in the next period by 0.91%, while keeping all other states constant. This confirms the fact that more productive firms are more profitable and often find themselves better off by expanding their production capacities. From section 1.6.2, I

[29] Recall that demand elasticity η is a negative number and its absolute value is larger than 1.

obtained the result that private firms are more likely to realize a higher productivity the next year than SOEs with similar characteristics. In turn, the potential to be more productive increases private firms' willingness to invest relative to SOEs. I add the measure of market conditions PI_{it} in Model 2 in order to see how macroeconomic components affect firms' investment decisions. The insignificant parameter belies any effects of market price indexes on investments and it seems that the firms make their investment decisions mainly based on their own states. Therefore I do not include PI_t in the following models. All other estimates in Model 2 are similar to the ones in Model 1. In Model 3, I assume that private firms and SOEs face different marginal effects of capital and productivity on investment. However, the two interaction terms $k_{it} * \rho_{it}$ and $\omega_{it} * \rho_{it}$ do not show significant effects. In the last model, I add all possible second- and third-order terms to make the specification as flexible as possible. All results are similar to the ones in previous models, except that the magnitude of coefficients changes dramatically, which is not surprising since I added many terms highly correlated with the regressors in previous models. Notice that I obtain a significant negative coefficient on k_{it}^3, which is actually very important for my simulations. The negative coefficient ensures that a firm's capital evolves according to a diminishing marginal effect, such that its capital will not become infinitely large when forward-simulating for many years into the future. This is why I need a model that is sufficiently flexible and is also the main reason I chose to use this model in the second estimation stage.

In the second group (Model 5 to Model 8), I regress physical investment (not logged) on firms' states. The results are reported in Table 2.5. The specifications of these models are very similar to the four models in the first group. Most results derived in the first group are confirmed here. In addition, we see that larger firms invest more in general and these increases in investments are more prominent in private firms than in SOEs.[30] This can be explained by the fact that private firms on average realize a higher productivity in the next period according to my estimates of the productivity evolution function; higher expected productivities improve private firms' potential for making profits and encourage them to arrange more investments. Notice that in Model 8 I am not able to include as many regressors as in Model 4 because some variables could form a deficient matrix that significantly diminishes the quality of my estimates.

In my last group of regressions, I change the dependent variable to investment per unit of capital and run similar regressions again. We see from Table 2.6 that, even though larger firms invest more in general, the investment per unit of capital actually decreases with larger firm size. Further more, these regressions confirm the tendency for highly productive firms to invest more. A one unit increase in productivity grows investment per unit of capital by 2.24 to 3.23 units, depending on the model specifications. In addition, I do not see a significant effect of ownership type on investment per unit of capital in these models.

2.5.5 Entry Decisions

In this subsection, I report my estimates on firms' entry decisions. On average, 890.571 firms enter the market each year, as shown in Table 2.7. Therefore, I assume the actual number of entrants is drawn from a Poisson distribution with a mean of 890.571. Among all entrants, 4.299% are state-owned and the rest are private. The distributions of initial log real capital are estimated separately for state-owned entrants and private entrants. More specifically, I apply a kernel density estimation with a normal kernel smoothing function and the optimal bandwidth for normal density. The distributions of initial log real capital are presented in Figures 2·2 and

[30] This is because the coefficient on $k_{it} * \rho_{it}$ is positive (0.052 in Model 7 and 0.053 in Model 8) and significant.

2·3 for private and state-owned entrants, respectively. In both graphs, the left panel is a histogram plotted with observed data and the right panel shows the corresponding probability density function estimated nonparametrically. Likewise, the distributions of entrants' productivities are estimated in a very similar fashion and reported in Figures 2·4 and 2·5. In the second stage of my estimation, I am going to draw entrants' initial states from these distributions.

With my estimated distributions of entrants' initial states, I can also calculate and list their means, standard deviations and quantiles to compare state-owned entrants with private entrants. Table 2.8 presents such information. The initial log real capital is on average 8.311 among private entrants, which is less than that of state-owned ones by 0.204. This is not surprising, because firms with governments' money are usually much larger than private firms. However, state-owned entrants draw their initial capital from a much more widely spread distribution than private ones (26.448% higher in standard error). This means that governments are much more flexible in adjusting their firms' sizes. In addition, the average productivity of private entrants is smaller than that of state-owned ones by 0.022 (0.203 versus 0.225). Therefore, even though SOEs are on average less productive than private firms, the newly formed SOEs are no worse in this respect than new born private firms.

2.5.6 Structural Parameters

At the very end of this section, I present the estimates of my structural parameters, $\theta = \{C_K^P, C_K^S, C_a, \bar{\phi}\}$. As a reminder, I need to estimate a term in investment adjustment cost C_a, per unit investment cost for both SOEs C_K^S and private firms C_K^P, and average scrap value $\bar{\phi}$. I simulate 500 times in total and then use their means as my point estimates of these parameters[31].

[31] 500 simulations are enough for us to obtain reasonable estimates, and yet not too time consuming. Of course, more simulations would yield more accurate estimates and smoother looking histograms, but I am always mindful of the high cost of running more simulations.

The mean, standard error, 5 percentile, and 95 percentile of these 500 simulations are reported in Table 2.9. On average, a firm obtains 365.630 thousand RMB upon declaring bankruptcy. Upon closing, 90% of all firms are worth between 150.016 and 773.783 thousand RMB. C_a is estimated to be 0.0166, which is lower than but comparable to the same measure for the Korean electric motor industry (0.0441) reported in Xu (2008).

Most interestingly, my estimates of per unit investment costs confirm the well-documented evidence that SOEs in China receive easy access to credits from state-owned Chinese banks, while private firms face significant financial constraints, especially for capital goods purchases. Notice that the mean level of per unit investment costs for private firms, $C_K^P = 0.0095$, is 25% higher than that for SOEs, $C_K^S = 0.0076$. It suggests a very probable inclination of banks to lend money to SOEs rather than to private firms. To test whether the difference between C_K^P and C_K^S is significant, I perform the following hypothesis test,

$$H_0: \quad C_K^P - C_K^S \leq 0$$

$$H_1: \quad C_K^P - C_K^S > 0.$$

The test statistic is 8.029, which is associated with a p-value smaller than 0.005 when compared to a t-distribution.[32] Therefore I can confidently conclude that SOEs pay a lower price for their investments at any reasonable significance levels.[33]

Finally, I plot the histograms of my estimates for these four dynamic parameters in Figures 2·6, 2·7, and 2·8. The mean levels are also represented in those figures by solid vertical lines. The estimates of C_a in Figure 2·6 are nicely concentrated around the mean with a small standard deviation. On the other hand, the distribution of scrap

[32]I can also do a test using the matched sample technique. The t-statistic calculated in this case is 8.832, implying a p-value much smaller than 0.005. Therefore, I can make the same conclusion if realizing that the sample is matched.

[33]Please see the appendix for the details of this hypothesis tests.

values in Figure 2·7 appears to spread out more. I plot the per unit investment cost for private firms and SOEs side by side in Figure 2·8 in order to compare them easily. From the figure, we see that the mass of C_K^P is more spread out, but definitely larger than the mass of C_K^S. Interestingly, most SOEs' per unit investment costs are below the average level, because the histogram skews to the right with few observations located on the upper tail. This provides further evidence of SOEs' easy access to credit.

2.6 Policy Simulations

Once I have obtained a complete set of parameter estimates, I can use the estimated model to simulate market evolution under different circumstances and answer some very important questions. At the beginning, I look at a situation where SOEs have to pay the same investment price as private firms. The second group of simulations exploits alternative selection schemes by governments. Finally, I focus on the two main channels of market reform, encouraging new entrants and privatizing existing SOEs, and isolate the effects of one channel from the other. In the following several subsections, I discuss these alternative policies in detail and quantify their possible effects.

2.6.1 Prohibiting Easy Access to Credit

I start with a simulation without making any changes to my original estimates; it is called the benchmark case and all other simulations are going to be compared to it. I take the estimates of the dynamic parameters in Table 2.9 as given and find equilibrium policies for all selected states by solving for a fixed point of the value function. More specifically, I start with zero values for all states and continuously solve for the left-hand side of equations (2.4) and (2.5) until they converge. Then the optimal policies are defined to be the best decisions revealed in the last loop right before convergence. Since there are four different state variables in my model, the number of possible combinations of these states can easily exceed several million, which makes solving equilibrium policies nearly impossible within a reasonable time span.[34] Therefore, I have to greatly simplify the process, which is discussed in much detail in the appendix.

Once equilibrium policies are found, I start with a market condition identical to the one in my 1997 data and simulate its evolution for 10 consecutive years. Then I use the simulated data set to calculate market statistics to inspect how it works. There are five groups of statistics considered in general: TFP improvement, physical capital, privatization, turnover, and entry. All are listed in the first column of Table 2.10, and the corresponding numbers for the benchmark case are presented in the second column of the same table.

First of all, I want to compare how my benchmark simulation works compared to my original data set. Since the benchmark simulation is carried out with original model estimates, its statistics should be close enough to the ones calculated from the actual data. Otherwise, my model estimates or simulation process need careful checking. As seen from Table 1.8, an average (weighted measure) private firm is 36.632% (0.308 compared to 0.225) more productive than an average SOE. Similarly, the simulated benchmark market sees a 34.219% (0.308 compared to 0.230) difference, which is very close to the number derived from my dataset. In addition, privatization on average (weighted measure) improves firms' productivities by 43.462% (from 0.253 to 0.364) as shown in Table 1.8, whereas the benchmark simulation gives us a very close measure of 39.058% (from 0.248 to 0.344).

In addition to a simulation with original estimates of the model, I carry out another simulation similar to the one above, but force SOEs to pay the same per unit

[34] My unsimplified version of the code needs more than three years to finish running, assuming convergence happens within 10 loops. However it is very likely that the convergence would take more than 10 loops.

investment cost as private firms.[35] The same set of statistics is calculated as in the benchmark case and presented in the third column of Table 2.10.

Even though the numbers are a bit different, most results about TFP in the "no easy access" case are in accordance with the ones in the benchmark. An average private firm is 33.676% more productive than an average SOE, whereas privatization can improve TFP by 37.593%. However, once SOEs' easy access to credits is prohibited, their TFP improves by 0.4% (from 0.230 to 0.231) and does not lag as far behind that of private firms. This is probably because SOEs can no longer rely on overinvesting in capital to fulfill their production due to more expensive loans, and their existing capital become more efficient.

The most obvious difference between these two simulations is the firms' sizes. Once SOEs' easy access to credits is removed, their average size decreases by 4.150% (from 187.562 to 179.778 thousand RMB). This is consistent with my expectation that SOEs under the new condition have to cut back the purchase of capital goods, because they are now more expensive. According to the policy "grasp the large and let go of the small," we know that being smaller in size increases SOEs' chances of privatization or termination. This phenomenon is confirmed by my statistics: the percentage of SOEs privatized rises from 12.191% to 12.206%, and SOEs' average termination rate increases from 12.628% to 12.945%. I do not see much change in firms' entry behavior

2.6.2 Possible Variations of Privatization Policy

As described above, the privatization process in China is selective and the probabilities that a firm is to be privatized or terminated depend on its characteristics. The selections are mainly based on two factors, real capital level (size) and productivity.

[35]Details about the simulation process and the numbers used for parameters can be found in the appendix.

The evidence in Table 2.3 indicates that smaller firms are more likely to be privatized or terminated, consistent with the "grasp the large and let go of the small" policy. In addition, more productive SOEs are more likely to be privatized rather than terminated. In the following two subsections, I take a closer look at these two types of selection, respectively, and investigate the possible effects of alternative policies.

Privatization Selection on Firm Size

In this subsection, I focus on two alternative policies. The first eliminates all possible selection based on firm size. To do this, I eliminate the dependence of governments' decisions on SOEs' capital levels in equation (2.13). The second alternative assumes the exact opposite policy, which can be summarized as "grasp the small and let go of the large." In other words, the larger the firm, the more likely it is to be privatized or terminated. To implement this policy, I force the coefficients on capital in equation (2.13) to take the opposite sign.[36] The statistics of the markets simulated under these two alternatives are presented in the third and fourth columns of Table 2.11. For easy comparison, I also present the benchmark statistics in the second column of the same table.

As the policy progresses from the benchmark, "grasp the large," to the other extreme, "grasp the small," the average TFP of SOEs decreases gradually from 0.230 to 0.202, and then to 0.199. Studies have shown that China's large SOEs are relatively more efficient and competitive, while the smaller ones suffer from serious losses. Therefore, once governments start to privatize those large SOEs, state-owned enterprises appear to be less productive on average. In contrast, private firms become more efficient (from 0.308 to 0.310, and to 0.311), not only because large capable SOEs are privatized, but also because the remaining, smaller SOEs are unable to compete with private firms. As a result, the percentage difference in TFP between private and

[36] Detailed explanations of how these two simulations are carried out can be found in the appendix.

state-owned firms increases from 34.219% to 53.589% and to 56.419%. On an industry level, the average firm productivity under “grasp the small” is 1.980% (from 0.302 to 0.308) higher than that under “grasp the large.” Recall that the main reason that governments retain large SOEs is that they do not want the reform to proceed so dramatically as to shake the basis of a politically stable environment. Therefore, the increase in productivities when governments grasp the small instead of the large can be explained by their incentive to trade off some productivity improvements for stable economic development.[37]

Probably the most obvious and expected effects of these alternative selection schemes are the changes in firms' sizes. The mean SOE capital values for both alternatives (“no selection” and “grasp the small ”) are both significantly smaller than that of the benchmark, “grasp the large”. As long as governments do not intentionally retain the large SOEs, the average size of the remaining SOEs drops significantly. At first glance, it might be surprising to see that the average size of SOEs under the “grasp the small” policy is larger than that under “no selection.” However, SOEs' average size relates to governments' privatization and termination decisions that depend greatly on firms' productivities as well. Therefore, it is possible that governments want to “grasp” a small SOE but cannot because this SOE is too inefficient to be retained.

Under the “no selection” alternative, both the percentage of SOEs privatized and the mean privatization rate are a little under five times higher than those calculated from “grasp the large” (from 12.191% to 55.009% for the percentage of SOEs privatized and from 2.018% to 9.303% for the mean privatization rate). The reason behind such a big difference is that, when large SOEs are not protected by governments, they are as likely to be privatized as comparable small SOEs. A similar result can be seen in the average termination rate for SOEs (increasing from 12.628% to 27.366%),

[37]Notice that one of the draw backs of this model is that we are not able to incorporate social stability into government decisions, because it is difficult to quantify social stability.

and the explanation is very similar too. The hypothetical policy "grasp the small" generates a similar privatization rate and SOE termination rate (9.165% and 29.386%, respectively) as the "no selection" case, but the former is lower while the latter is higher than the corresponding counterparts. I believe this has to do with SOEs' productivity, which also affects their probability of being selected. First, I am not surprised that the privatization rate under "grasp the small" is smaller than that of "no selection," because any intentional protection from governments, no matter what type of firms are protected (large or small), can mitigate the degree of privatization. On the contrary, according to the same reasoning, the result that the SOE termination rate under "grasp the small" is higher than that of "no selection" seems peculiar. However, we need to consider the fact that small SOEs are relatively less productive. It is possible that the effects of low productivity on the probabilities of being terminated outweighs those of "grasp the small."

Privatization Selection on Firm Productivity

Governments' privatization and termination decisions also depend on firms' productivities. In this subsection, I take a look at an alternative policy that does not select on firms' productivities.[38] In Table 2.12, I report in the second column the statistics of a benchmark that is referred to as "selection on productivity" in this case, and the third column presents statistics for the "no selection" alternatives.

First, almost all average productivity measures under "selection on productivity" are higher than those under "no selection." Especially, the mean TFP of privatized SOEs before privatization decreases by 33.871% once selection is eliminated (from 0.248 to 0.164). This indicates that if higher productivity does not increase SOEs'

[38] Some curious readers may ask why I do not simulate a policy in which privatization and termination are selected inversely to productivities, similar to what I did in the previous subsection. The reason is that I believe it is meaningless to investigate what would happen if governments privatized the less productive SOEs but closed the more productive ones, because it seems that such an unreasonable policy would never be implemented in the first place.

chance of being privatized, the SOEs selected for privatization are on average less productive. In addition, the TFP percentage difference between private and state-owned firms increases by 9.954 percentage points (from 34.219% to 44.173%) because many more efficient SOEs are terminated under the "no selection" alternative. TFP improvements from SOEs to private firms increase by 35.897 percentage points (from 39.058% to 74.955%) for similar reasons.

The mean capital value of SOEs is much lower when there is no selection on productivity (92.080 thousand RMB compared to 187.562 thousand RMB). To explain this phenomenon, notice that the mean TFP of SOEs is reduced, which indicates that more efficient SOEs are reformed under "no selection." In conjunction with the fact that large SOEs are in general more efficient, we know that the size of remaining SOEs must be smaller.

The privatization rate and SOE termination rate are 1.256% and 22.324%, respectively, under "no selection." The former is lower than the corresponding figure under "selection on productivity" (2.018%), but the later is higher (compared to 12.628%). This is probably because many SOEs are in fact performing well, and these SOEs should be privatized instead of being closed if governments decide to give more productive SOEs a second chance.

2.6.3 Two Channels of Market Reform

Governments took two different routes simultaneously to transform China's economy. First, they not only permitted but also encouraged the establishment of private firms. Second, they privatized or terminated existing SOEs and released resources and opportunities to other (probably more efficient) firms in the market. In this section, I try to separate the effects of these policies by shutting down one or the other channel and simulating the effects on markets. In the third column of Table 2.13, I report the statistics of a simulation where entry is prohibited. The fourth column presents the statistics of a simulation that cancels any privatization and termination. The benchmark simulation is presented in the second column for easy comparison.

First of all, there is no firm entry under "reform only" as shown at the bottom panel of Table 2.13. Interestingly, the average firm sizes of both private and state-owned firms are much larger in the "reform only" case, especially the existing private firms (mean capital value of 575.439 thousand RMB, compared to 181.424 thousand RMB in the benchmark). When the market is expanding and there is no new firm to fill the demand, existing firms can grow much larger than usual. A related result is that the privatization rate is higher (from 2.018% to 2.030%) but the termination rate is almost cut in half (from 12.628% to 7.023%). Once again, when there are no new entrants to meet the demand, governments try to privatize more SOEs instead of closing them. The firms in general become more efficient (0.316 compared to 0.302) and I believe that the reason must have something to do with economies of scale because all firms are much larger when there is no entry. Recall that private firms in the "reform only" environment become much larger and their changes in size are much more noticeable than those for SOEs. Therefore, economies of scale can also explain why SOEs lag further behind private firms in terms of TFP (56.197% difference in TFP between private and state-owned firms compared to 34.219% in the benchmark). Finally, new firm enter is the main source of market transformation because the total number of observations (16,560) drops to one-third that of the benchmark case (52,052).

Under a market with "entry only," there is no privatization or termination, as shown in the far right column of Table 2.13. The average TFP of SOEs is lower than that under "entry and reform" (0.208 compared to 0.230) because an SOE will never be privatized even if it performs very poorly. Not surprisingly, average firm sizes of both SOEs and private firms are smaller under "entry only" (168.144 and 176.484, respectively) compared to "entry and reform" (187.562 and 181.424, respectively), because new entrants are usually small firms.

2.7 Conclusion

In conclusion, this paper constructs a dynamic structural model to study China's recent economic reform. The model is estimated with the technique proposed by Bajari, Benkard, and Levin (2007), and the results confirm our expectation on many observed institutional features. In addition, policy simulations are carried out with the help of my estimated model, and I am able to answer several important questions that were difficult to address without such a model.

Of course, there are always areas where improvements can be made. First, governments are not strategic players in this model and their actions are estimated with reduced-form regressions. Therefore, I am not able to know how governments would react to changes in firms' behavior. Second, since the reform in China was still in progress during our sample period, I can model changes in investment costs over time according to a basic time series model. Then I might be able to derive some direct proof of the transformation of China's financial market. Lastly, mass layoffs can be dynamic, and the number of laid-off workers may depend on market conditions. If this is the case, the way we deal with mass layoffs in this paper may be too coarse, and a model that specifies firms' labor choices as a function of market states is needed.

2.8 Appendix

2.8.1 Testing Lower Investment Price for SOEs

To test whether the per unit investment cost for SOEs is significantly lower than that for private firms, I construct the following hypothesis test,

$$\begin{aligned} H_0: &\quad C_K^P - C_K^S \leq 0 \\ H_1: &\quad C_K^P - C_K^S > 0. \end{aligned} \tag{2.23}$$

To perform the test, I follow a procedure of inferences about the difference between two population means when standard deviations are unknown. The test statistic can be constructed using the following formula,

$$t = \frac{C_K^P - C_K^S}{\sqrt{\frac{s_P^2}{n_P} + \frac{s_S^2}{n_S}}}$$

where s_P and s_S are standard deviations of C_K^P and C_K^S estimates, respectively, which are reported in Table 2.9, and n_P and n_S are corresponding sample sizes, which are both 500 in this case. Under some familiar assumptions, the test statistic follows a t distribution with degrees of freedom

$$df = \frac{(\frac{s_P^2}{n_P} + \frac{s_S^2}{n_S})^2}{\frac{1}{n_P-1}(\frac{s_P^2}{n_P})^2 + \frac{1}{n_S-1}(\frac{s_S^2}{n_S})^2}.$$

After calculation, $t = 8.029$ and $df = 716.667$. The resulting p-value is well below 0.005, which supports the alternative hypothesis for any reasonable levels of confidence.

One may realize that my sample is matched in the sense that, for each simulation, I obtain an estimate of C_K^P and an estimate of C_K^S, and a difference between C_K^P and C_K^S, called d, can be calculated. Then a regular t-test can be used to perform the test in equation (2.23). Let $\bar{d}$ be the average of d from all simulations, n be the sample size which is 500 in this case, and s_d be the standard deviation of d. The test statistic is defined by,

$$t = \frac{\bar{d}}{s_d/\sqrt{n}},$$

which is calculated to be 8.832. Under some familiar assumptions, the test statistic follows a t distribution with degrees of freedom $n - 1 = 499$. Therefore, the resulting p-value is again well below 0.005, and I arrive at the same result as the previous test.

2.8.2 Simulation Details

In this section, I discuss how I simulate the market. The most difficult step in running a simulation for a given set of parameters, θ, is to solve for equilibrium investment and exit strategies.[39] A regular method of accomplishing this is to discretize each state variable and numerically solve for the fixed point of firms' value function. However, this is very difficult to do, and it may take years for the program to converge. Instead, I will take advantage of the fact that profit in the far future contributes very little to firms' value today because of discounting, and use backward induction to find the value function as well as optimal strategies. Once the equilibrium strategies are known, simulation of the market is easy and runs very fast. All I need is to make sure all firms behave as described by the strategies and then keep the market evolving accordingly.

Solve for Equilibrium Strategies

As mentioned immediately above, it is a very processor demanding process to solve for equilibrium strategies. To overcome this problem, I use backward induction instead of trying to calculate a fixed point. I first discretize each state variable and list

[39] Note that I did not need to find the equilibrium strategies when estimating the model because I was using the BBL and the equilibrium strategies were solved by reduced-form regressions in the first stage.

all possible combinations.[40] For each listed combination of states, $(\omega_{it}, k_{it}, \rho_{it}, S_{-it})$, I start with the value function, $V(\omega_{it}, k_{it}, \rho_{it}, S_{-it}; \sigma^*, \theta)$, when $t = 101$ and assume their values are all zeros because those numbers are insignificant to the value function when $t = 1$ due to the compounded discount factor β^t. Then I can update the values for each listed combination of states when $t = 100$, according to the firms' Bellman equations (equations (2.4) and (2.5)). Once I am given the values at $t = 100$, I am able to solve the values when $t = 99$. I keep performing this updating until I reach the current period, $t = 1$. The advantage of this method is that, even though updating the values for all combinations of states is time consuming, I am guaranteed to finish running the program after 100 updates. Unfortunately, even this method is difficult to implement and can take months to run. Therefore, I am forced to do further simplifications and realize that I may be able to make the state of all other firms deterministic.

Recall that a nice simplification of this model is that the states of all other firms, S_{-it}, can be aggregated as a single price index, PI_t. In addition, the most important factor that affects the value of PI_t is the number of firms in the market, which can be seen from equation (1.9). Given the fact that the number of firms in the market is fairly stable and most of firms' decisions do not depend on PI_t, I can assume the price index is deterministic and does not change if a single firm deviates from its optimal strategy. Hence the estimation can be further simplified. I take the price indexes in the first 10 years (from 1997 to 2006) as given in the dataset, and interpolate the price indexes for the next 90 years according to a regression with a flexible functional form indicating the dependency of PI_t on PI_{t-1}. Then I am able to rerun the algorithm presented in the previous paragraph without integrating over different levels of price indexes. In addition, since price indexes are deterministic, the number of possible

[40] Log real capital ranges from 0 to 16.95 with an increment of 0.05, productivity ranges from -0.31 to 1 with an increment of 0.005, and private state can be either 0 or 1.

combinations of states is much less than in the previous version. In this case, 100 updates can be done within 24 hours.[41]

Simulate according to Equilibrium Strategies

Once I have solved the equilibrium strategy, simulation can be done easily and the program usually takes less than 30 seconds to terminate. For all simulations considered in this paper, I start with a market condition that is the same as the one in my data at year 1997, and simulate for 10 years. It is important to note that I have only solved for the equilibrium investment function and private firms' exit choices in the previous step. I reuse governments' privatization and termination choices for SOEs, entering decisions, as well as the profit function and productivity evolution function calculated in section 2.5. Unlike the previous step where I solve for equilibrium strategies, the price indexes are not predetermined. As long as firms are able to update their states according to equilibrium strategies, the price indexes that represent market conditions can be calculated using equation (1.9).

Simulations of Policy Changes

In this section I describe exactly how the simulation of each case studied in section 2.6 is carried out. In section 2.6.1, I force SOEs to pay the same investment price as private firms. In order to do that, I set SOEs' per unit investment cost C_K^S to be 0.0095, which is the per unit investment cost for private firms C_K^P, and then solve for new equilibrium strategies that are used in the simulation.

In section 2.6.2, I run two different simulations: (1) a market where privatization and termination do not depend on firm size and (2) a market that follows the "grasp the small and let go of the large" policy. In the first simulation, I alter the government's privatization and termination policy such that the coefficients of log real

[41] The Matlab programs themselves are available upon request.

capital are zero ($\beta_2^p = 0$ and $\beta_2^t = 0$ in equation (2.13)). With other policy functions unchanged, I am able to solve equilibrium strategies and simulate the market. To simulate for "grasp the small and let go of the large," I follow a very similar procedure as above, except that I reverse the sign of the coefficients of log real capital in equation (2.13) ($\beta_2^p = 0.248$ and $\beta_2^t = 0.110$).

The simulation process in section 2.6.2 is very similar to the one in section 2.6.2. I once again alter the governments' privatization and termination decisions. Recall in Table 2.3 that the parameters on productivity in Model 2 are $\beta_1^p = 2.607$ and $\beta_1^t = -4.109$ for privatization and termination, respectively. The numbers indicate that the governments intentionally choose more productive SOEs to be privatized and less productive ones to be terminated. In order to simulate an environment in which the governments' decisions have nothing to do with firms' productivity, I set both β_1^p and β_1^t to zero so that productivity does not affect the probability of being privatized or closed. Then I solve for new optimal strategies and simulate the market.

My last simulation, introduced in section 2.6.3, attempts to discern the effects of isolating two different channels of the reform: (1) new firm entry and (2) privatization. To see the effects of privatization only, I stop firm entry and make sure there are no new firms in all years of the simulation. This can be done simply by setting the average number of entrants, $M(S_t)$, to zero. To investigate the effects of entering only, I do not allow governments to privatize or terminate any SOEs by setting the probabilities, $F(\rho_{it+1} = 0 \mid \omega_{it}, k_{it})$ and $F(\rho_{it+1} = 1 \mid \omega_{it}, k_{it})$, to zero for all firms i at any time t.

Table 2.1: Evidences of Easy Credit for SOEs

Parameters	Model 1	Model 2	Model 3
$const$	121.136	115.780	
	(5.847)***	(5.835)***	
$Private\,Dummy$	-11.911	-12.497	-6.227
	(6.124)*	(6.101)**	(9.273)
$Added\,Value$		$9.465 * 10^{-5}$	$3.879 * 10^{-5}$
		$(0.665 * 10^{-5})$***	$(0.653 * 10^{-5})$***
$Main\,Operation\,Profit$		$-5.819 * 10^{-5}$	$-2.436 * 10^{-5}$
		$(1.417 * 10^{-5})$***	$(1.350 * 10^{-5})$*
$Wage\,Rate$		0.076	0.029
		(0.014)***	(0.011)***
Fixed Effect			✓
Num of SOEs	3858	3858	3858
Num of Private Firms	39852	39852	39852
Sample Size	43710	43710	43710

* significant at 10%, ** significant at 5%, *** significant at 1%.

Table 2.2: Private Firms Exit Choice

Parameters	Model 1	Model 2	Model 3
$const$	-1.062	-1.058	-0.623
	(0.137)***	(0.146)***	(0.444)***
k_{it}	-0.125	-0.125	-0.174
	(0.017)***	(0.017)***	(0.104)***
ω_{it}	-4.188	-4.187	-6.532
	(0.267)***	(0.268)***	(0.957)***
PI_t		$1.098 * 10^{-9}$	
		$(14.584 * 10^{-9})$	
Higher Order Terms			✓
Coefficient Test	203.416	135.618	128.904
P-value	0.000	0.000	0.000
Likelihood-ratio Test	526.006	526.012	687.199
P-value	0.000	0.000	0.000
sample size	33784	33784	33784

Standard errors are in paraphrases.
* significant at 10%, ** significant at 5%, *** significant at 1%.

Figure 2·1: Game Tree: a graphic representation of my model

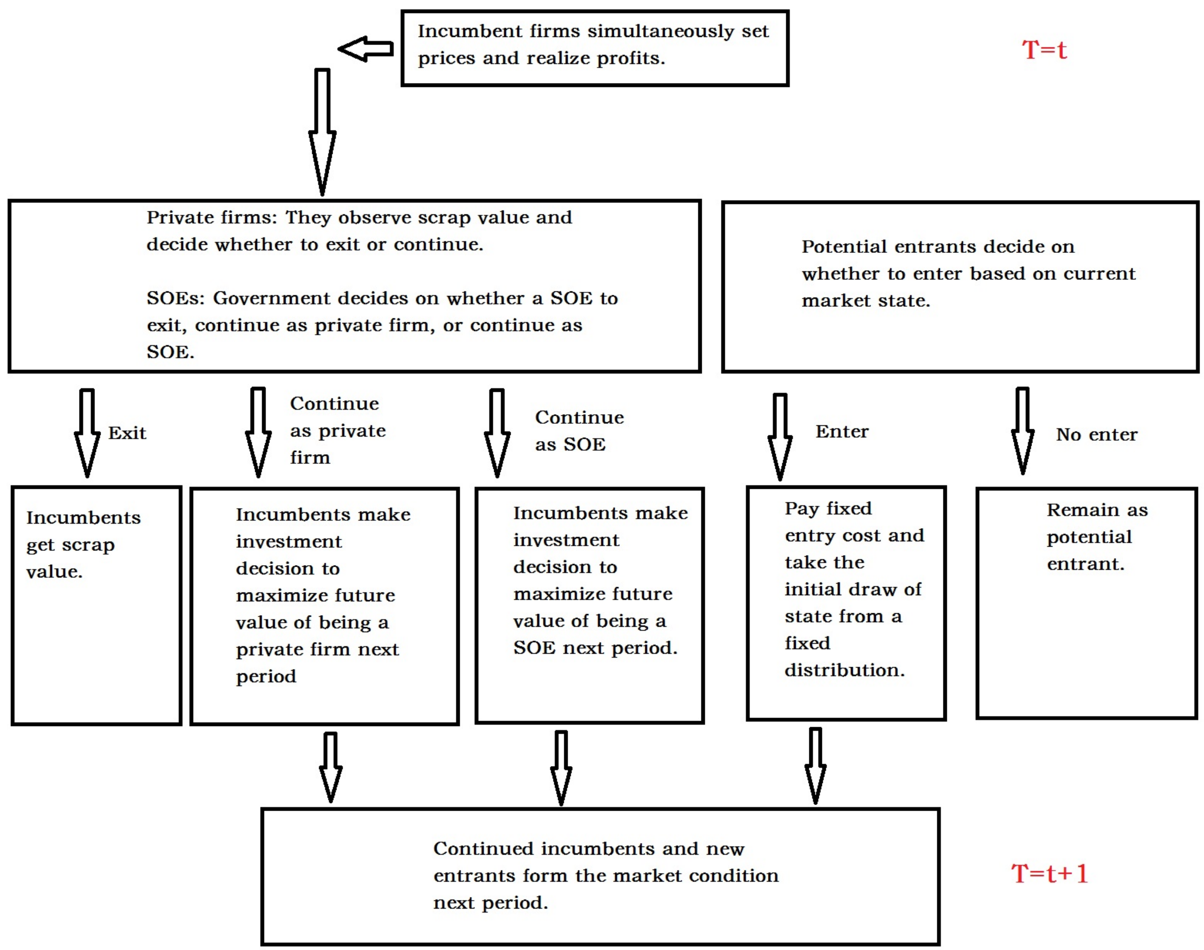


Table 2.3: SOEs Privatization and Exit Choice

	Model 1		Model 2		Model 3	
Parameters	Privatize	Exit	Privatize	Exit	Privatize	Exit
$const$	-0.880	-0.738	-0.508	-1.146	-5.641	-0.968
	(0.294)***	(0.283)***	(0.307)*	(0.299)***	(1.271)***	(0.814)
k_{it}	-0.248	-0.110	-0.255	-0.102	1.040	-0.174
	(0.035)***	(0.033)***	(0.035)***	(0.034)***	(0.306)***	(0.203)
ω_{it}	2.258	-3.632	2.607	-4.109	1.417	-3.299
	(0.414)***	(0.372)***	(0.419)***	(0.389)***	(2.057)	(1.589)**
PI_t			$-1.664 * 10^{-7}$	$-1.530 * 10^{-7}$	$-1.811 * 10^{-7}$	$1.529 * 10^{-7}$
			$(0.407 * 10^{-7})$***	$(0.316 * 10^{-7})$***	$(0.409 * 10^{-7})$***	$(0.317 * 10^{-7})$***
k_{it}^2					-0.079	0.005
					(0.019)***	(0.013)
ω_{it}^2					-1.095	2.289
					(1.755)	(1.512)
$k_{it} * \omega_{it}$					0.275	-0.149
					(0.258)	(0.187)
Likelihood-ratio Test	241.372		285.345		316.162	
P-value	0.000		0.000		0.000	
sample size	3858		3858		3858	

Standard errors are in paraphrases.
* significant at 10%, ** significant at 5%, *** significant at 1%.

Table 2.4: Investment Decision
Dependent: future log real capital

Parameters	Model 1	Model 2	Model 3	Model 4
$const$	0.761	0.759	0.707	2.703
	(0.020)***	(0.020)***	(0.052)***	(0.190)***
k_{it}	0.902	0.902	0.908	0.202
	(0.002)***	(0.002)***	(0.006)***	(0.053)***
ω_{it}	0.910	0.909	0.886	5.215
	(0.025)***	(0.025)***	(0.064)***	(0.410)***
ρ_{it}	0.066	0.065	0.126	-0.039
	(0.011)***	(0.011)***	(0.055)**	(0.166)
PI_t		$1.112 * 10^{-9}$		
		$(1.773 * 10^{-9})$		
k_{it}^2				0.074
				(0.005)***
ω_{it}^2				2.216
				(0.562)***
$\omega_{it} * k_{it}$				-0.854
				(0.090)***
$k_{it} * \rho_{it}$			-0.007	0.034
			(0.006)	(0.036)
$\omega_{it} * \rho_{it}$			0.027	-0.295
			(0.069)	(0.165)*
k_{it}^3				-0.002
				(0.000)***
ω_{it}^3				-0.980
				(0.434)**
$\omega_{it} * k_{it}^2$				0.035
				(0.006)***
$\omega_{it}^2 * k_{it}$				-0.089
				(0.070)
$k_{it}^2 * \rho_{it}$				-0.001
				(0.002)
$\omega_{it}^2 * \rho_{it}$				0.233
				(0.269)
Adjusted R-square	0.903	0.903	0.903	0.906
sample size	35268	35268	35268	35268

Standard errors are in paraphrases.
* significant at 10%, ** significant at 5%, *** significant at 1%.

Table 2.5: Investment Decision (Continued)
Dependent: investment (not logged)

Parameters	Model 5	Model 6	Model 7	Model 8
$const$	-15558.880	-14814.823	-5054.453	-11711.280
	(2175.858)***	(2290.623)***	(3015.652)*	(3037.277)***
k_{it}	0.150	0.150	0.104	0.759
	(0.002)***	(0.002)***	(0.005)***	(0.030)***
ω_{it}	52851.138	53153.948	26422.026	-45568.990
	(4209.846)***	(4219.913)***	(10784.471)**	(13584.657)***
ρ_{it}	7611.676	8061.996	-4813.321	12775.151
	(2087.161)***	(2131.665)***	(3275.637)	(3477.930)***
PI_t		$3.534 * 10^{-4}$		
		$(3.401 * 10^{-4})$		
ω_{it}^2				179887.857
				(18776.395)***
$\omega_{it} * k_{it}$				-2.198
				(0.097)***
$k_{it} * \rho_{it}$			0.052	0.053
			(0.005)***	(0.005)***
$\omega_{it} * \rho_{it}$			32537.054	-14861.655
			(11710.610)***	(12236.081)
$\omega_{it}^2 * k_{it}$				1.780
				(0.077)***
Adjusted R-square	0.193	0.193	0.196	0.210
sample size	35268	35268	35268	35268

Standard errors are in paraphrases.
* significant at 10%, ** significant at 5%, *** significant at 1%.

Table 2.6: Investment Decision (Continued)
Dependent: investment / real capital (not logged)

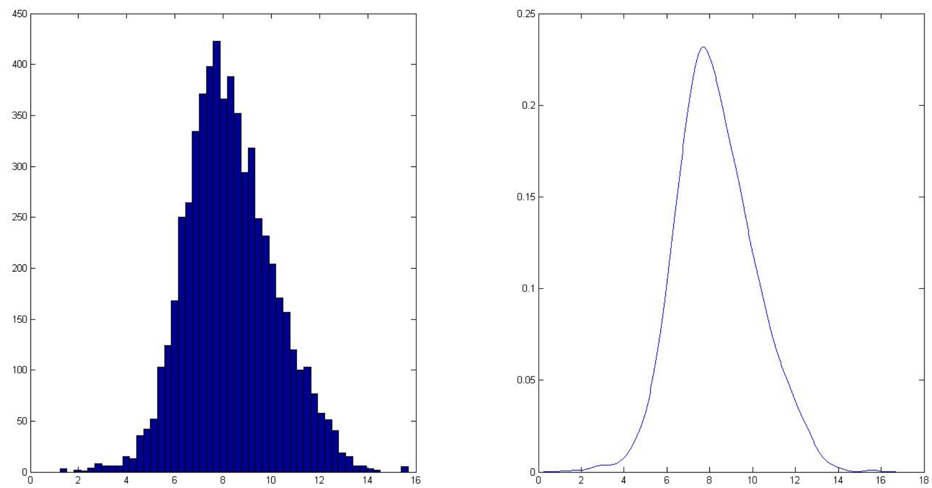
Parameters	Model 9	Model 10	Model 11	Model 12
$const$	0.399	0.361	0.206	0.335
	(0.377)	(0.397)	(0.523)	(0.532)
k_{it}	$-6.512 * 10^{-7}$	$-6.526 * 10^{-7}$	$-9.073 * 10^{-7}$	$-1.374 * 10^{-5}$
	$(3.112 * 10^{-7})$**	$(3.112 * 10^{-7})$**	$(8.725 * 10^{-7})$	$(0.533 * 10^{-5})$***
ω_{it}	2.240	2.225	3.230	5.389
	(0.729)***	(0.731)***	(1.871)*	(2.379)**
ρ_{it}	0.046	0.023	0.281	-0.175
	(0.362)	(0.369)	(0.568)	(0.609)
PI_t		$1.796 * 10^{-8}$		
		$(5.891 * 10^{-8})$		
ω_{it}^2				-5.352
				(3.288)
$\omega_{it} * k_{it}$				$3.933 * 10^{-5}$
				$(1.693 * 10^{-5})$**
$k_{it} * \rho_{it}$			$2.930 * 10^{-7}$	$9.535 * 10^{-8}$
			$(9.339 * 10^{-7})$	$(94.236 * 10^{-8})$
$\omega_{it} * \rho_{it}$			-1.164	0.122
			(2.032)	(2.143)
$\omega_{it}^2 * k_{it}$				$-2.820 * 10^{-5}$
				$(1.357 * 10^{-5})$**
Adjusted R-square	0.0002	0.0002	0.0002	0.0003
sample size	35268	35268	35268	35268

Standard errors are in paraphrases.
* significant at 10%, ** significant at 5%, *** significant at 1%.

Table 2.7: Entry Decision

Average Number of new entrants	890.571
percentage of state owned entrants	4.299%

Figure 2·2: Entrants Log Real Capital Distribution (Private Entrants)



Left panel shows the histogram of entrants' log real capital in my dataset. Right panel depicts the probability density function estimated using my dataset. Log real capital is on horizontal axis of both graphs, and number of observations is on vertical axis of the graph to the left, and probability is on vertical axis of the graph to the right.

Table 2.8: Simple Statistics of Entrant State Distribution

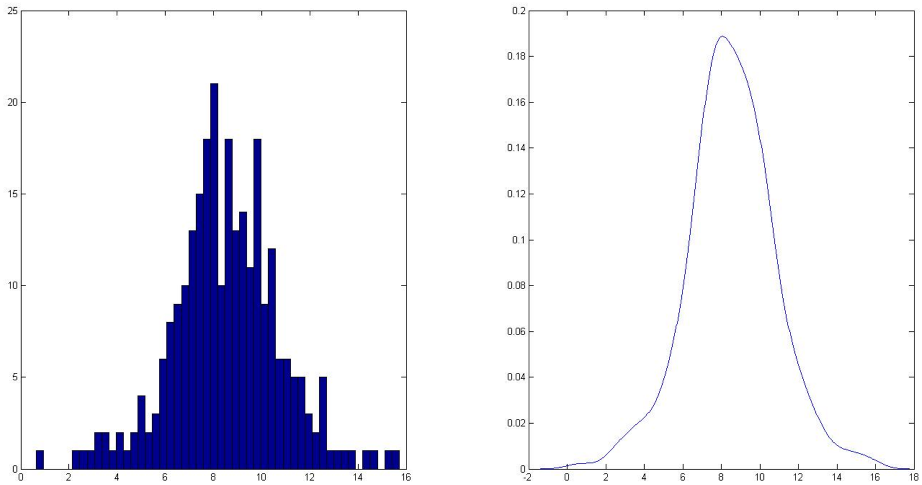
State	Ownership	Mean	Std Error	5 Percentile	95 Percentile
k^e	Private	8.311	1.864	5.517	11.628
	State Owned	8.515	2.357	4.558	12.368
ω^e	Private	0.203	0.124	0.053	0.447
	State Owned	0.225	0.189	-0.071	0.555

Table 2.9: Dynamic Parameter

Parameters	Mean	Std Error	5 Percentile	95 Percentile
$\bar{\phi}$	365.6299	186.4794	150.0155	773.7826
C_K^P	0.0095	0.0048	0.0029	0.0173
C_K^S	0.0076	0.0023	0.0048	0.0120
C_a	0.0166	0.0041	0.0116	0.0248

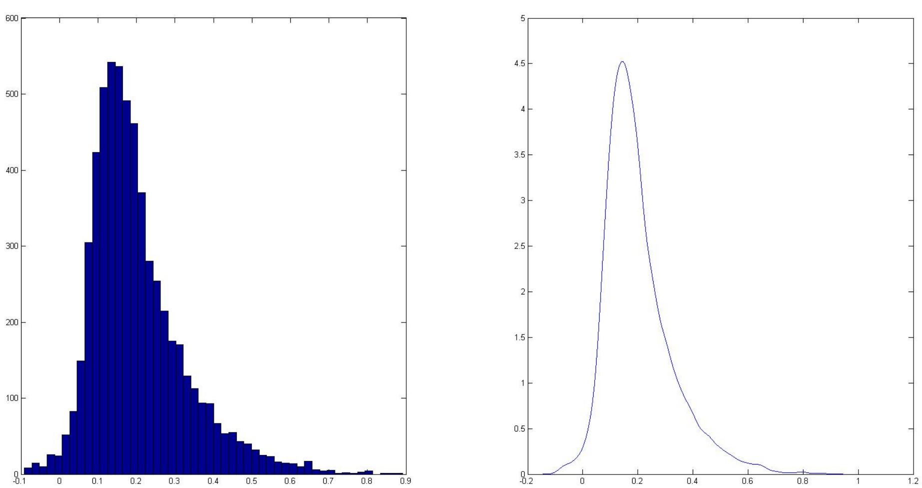
Total number of simulation is 500.

Figure 2·3: Entrants Log Real Capital Distribution (State Owned Entrants)



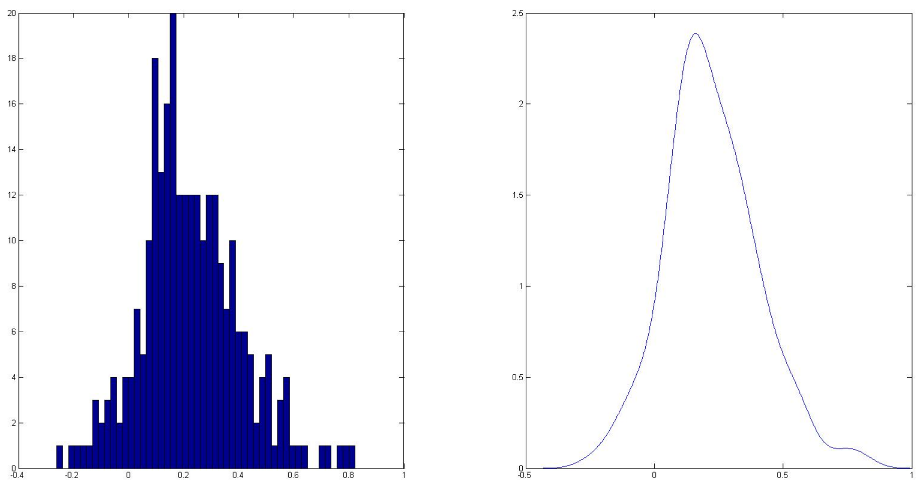
Left panel shows the histogram of entrants' log real capital in my dataset. Right panel depicts the probability density function estimated using my dataset. Log real capital is on horizontal axis of both graphs, and number of observations is on vertical axis of the graph to the left, and probability is on vertical axis of the graph to the right.

Figure 2·4: Entrants Productivity Distribution (Private Entrants)



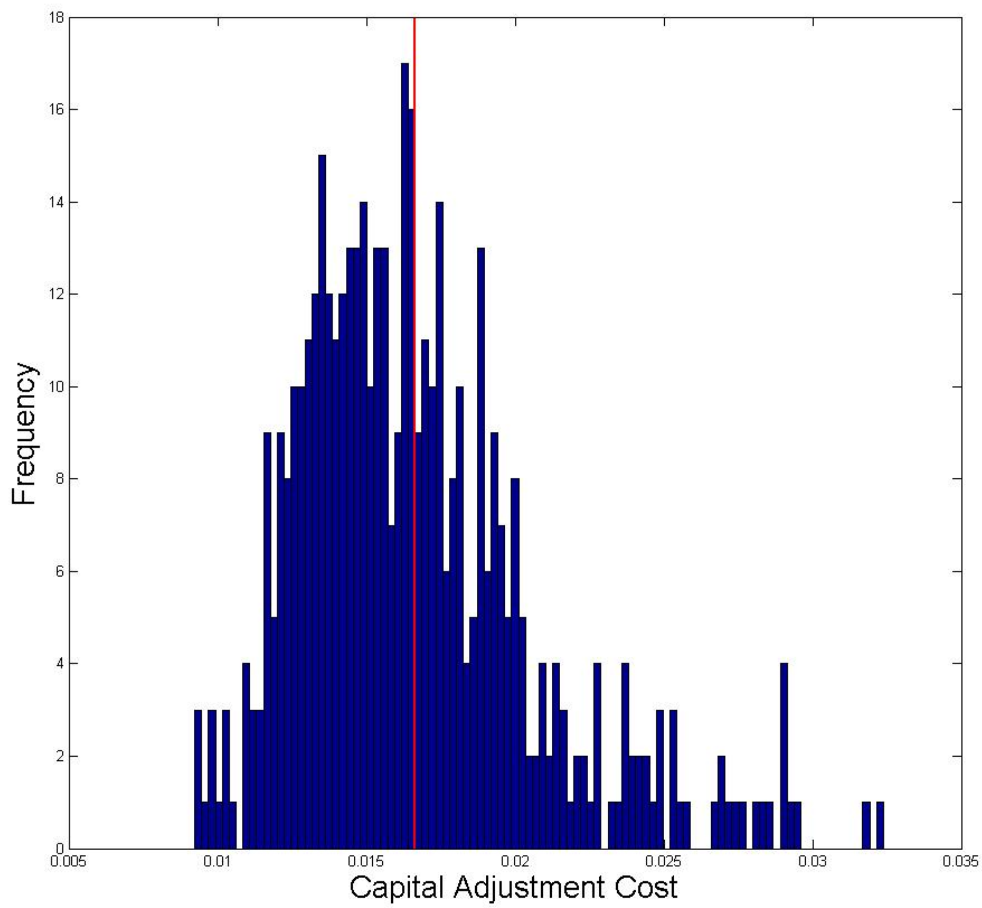
Left panel shows the histogram of entrants' productivity in my dataset. Right panel depicts the probability density function estimated using my dataset. Productivity is on horizontal axis of both graphs, and number of observations is on vertical axis of the graph to the left, and probability is on vertical axis of the graph to the right.

Figure 2·5: Entrants Productivity Distribution (State Owned Entrants)



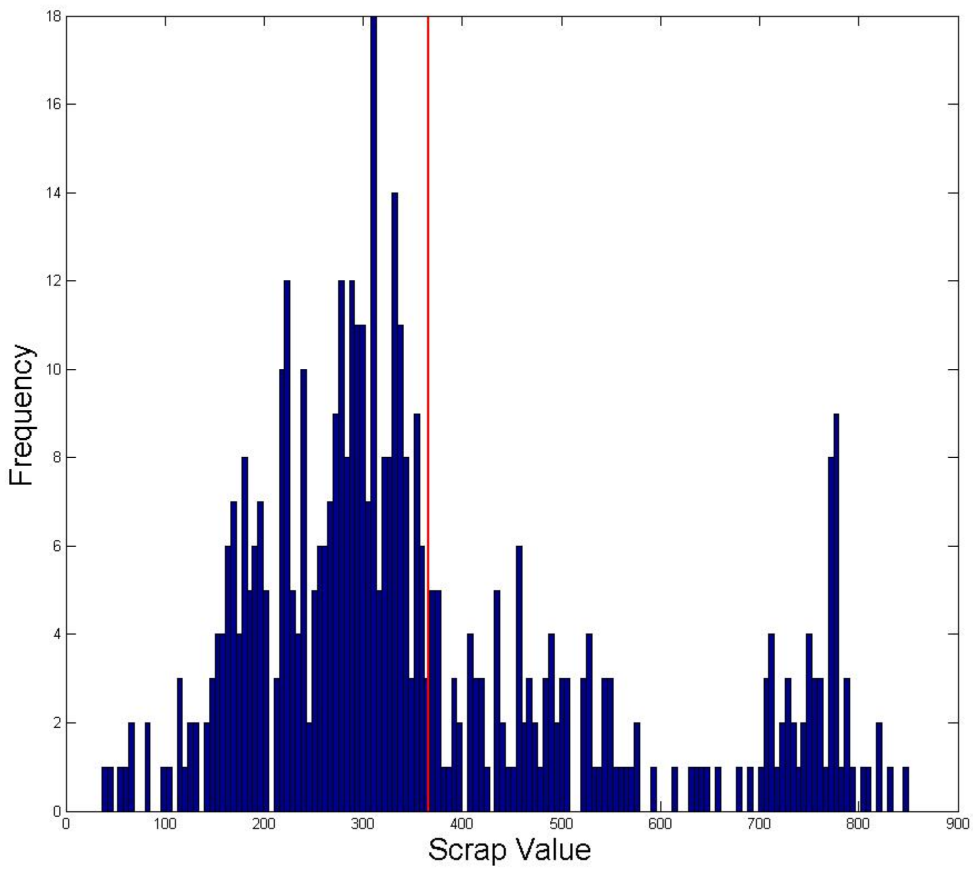
Left panel shows the histogram of entrants' productivity in my dataset. Right panel depicts the probability density function estimated using my dataset. Productivity is on horizontal axis of both graphs, and number of observations is on vertical axis of the graph to the left, and probability is on vertical axis of the graph to the right.

Figure 2·6: Distribution of Estimated Capital Adjustment Cost



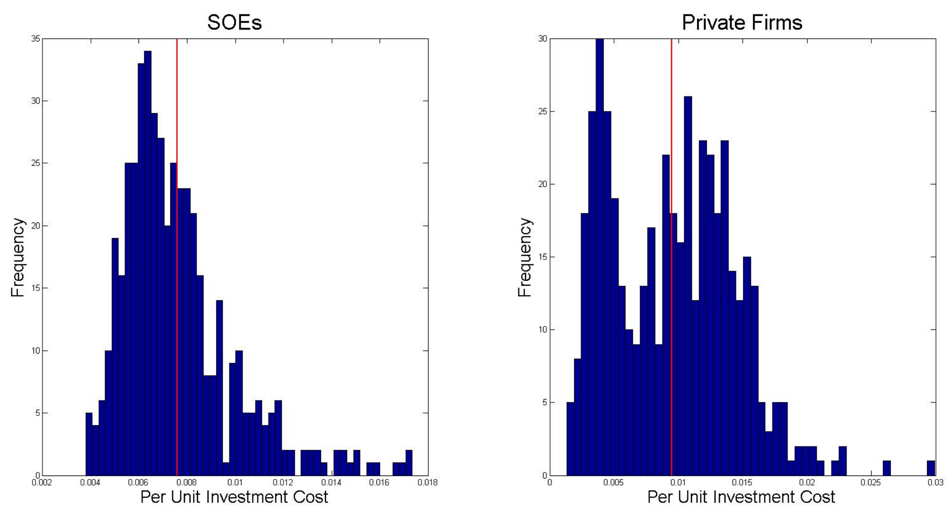
The vertical red line indicates the mean level of Estimated Capital Adjustment Cost. Capital Adjustment Cost is on horizontal axis, and number of Estimates is on vertical axis.

Figure 2·7: Distribution of Estimated Scrap Value



The vertical red line indicates the mean level of Estimated Scrap Value. Scrap Value is on horizontal axis, and number of Estimates is on vertical axis.

Figure 2·8: Distribution of Estimated Per Unit Investment Cost



The vertical red line indicates the mean level of Estimated Per Unit Investment Cost. Left panel shows the histogram of estimated Per Unit Investment Cost for State Owned Enterprises. Right panel depicts the estimated Per Unit Investment Cost for Private Enterprises. Per Unit Investment Cost is on horizontal axis of both graphs, and number of Estimates is on vertical axis of both graph.

Table 2.10: Statistics of Simulated Markets (Prohibiting Easy Access to Credit for SOEs)

Statistics	Easy Access	No Easy Access
TFP Improvement		
Mean (Weighted) Industry TFP	0.302	0.302
Mean (Weighted) TFP of SOEs	0.230	0.231
Mean (Weighted) TFP of Private Firms	0.308	0.308
TFP Percentage Differences Between Private and State-owned firms	34.219%	33.676%
Mean (Weighted) TFP of Privatized SOEs Before Privatization	0.248	0.254
Mean (Weighted) TFP of Privatized SOEs After Privatization	0.344	0.348
TFP Improvements from SOEs to Private Firms	39.058%	37.593%
Correlation Between Capital and TFP	0.424	0.426
Physical Capital		
Industry Mean Capital Value (Thousands)	181.934	181.528
Mean Capital Value of SOEs (Thousands)	187.562	179.778
Mean Capital Value of Private Firms (Thousands)	181.424	181.663
Privatization		
Number of Observations	52052	52100
Number of State-owned Observations	4167	4128
Number of Private Observations	47886	47972
Sample Size of Privatized SOEs Before Privatization	221	219
Sample Size of Privatized SOEs After Privatization	700	702
Percentage of SOEs Privatized	12.191%	12.206%
Mean Privatization Rate (Yearly)	2.018%	2.024%
Firm Turnover		
Mean Exit Rate (Yearly)	3.963%	3.961%
Mean SOEs Termination Rate (Yearly)	12.628%	12.945%
Mean Private Firm Exit Rate (Yearly)	3.312%	3.290%
Firm Entry		
Mean Number of Entry (Yearly)	889.897	891.396
Mean Number of State-owned Entrants (Yearly)	37.762	37.814
Mean Number of Private Entrants (Yearly)	852.134	853.581

Table 2.11: Statistics of Simulated Markets (Reform Selection on Firm Size)

Statistics	Grasp The Large	No Selection	Grasp The Small
TFP Improvement			
Mean (Weighted) Industry TFP	0.302	0.307	0.308
Mean (Weighted) TFP of SOEs	0.230	0.202	0.199
Mean (Weighted) TFP of Private Firms	0.308	0.310	0.311
TFP Percentage Differences Between Private and State-owned firms	34.219%	53.589%	56.419%
Mean (Weighted) TFP of Privatized SOEs Before Privatization	0.248	0.240	0.236
Mean (Weighted) TFP of Privatized SOEs After Privatization	0.344	0.342	0.342
TFP Improvements from SOEs to Private Firms	39.058%	43.053%	44.873%
Correlation Between Capital and TFP	0.424	0.439	0.452
Physical Capital			
Industry Mean Capital Value (Thousands)	181.934	185.165	193.927
Mean Capital Value of SOEs (Thousands)	187.562	26.117	37.045
Mean Capital Value of Private Firms (Thousands)	181.424	197.157	204.386
Privatization			
Number of Observations	52052	52148	52175
Number of State-owned Observations	4167	1619	1606
Number of Private Observations	47886	50528	50569
Sample Size of Privatized SOEs Before Privatization	221	786	771
Sample Size of Privatized SOEs After Privatization	700	3322	3319
Percentage of SOEs Privatized	12.191%	55.009%	54.199%
Mean Privatization Rate (Yearly)	2.018%	9.303%	9.165%
Firm Turnover			
Mean Exit Rate (Yearly)	3.963%	3.861%	3.875%
Mean SOEs Termination Rate (Yearly)	12.628%	27.366%	29.386%
Mean Private Firm Exit Rate (Yearly)	3.312%	3.248%	3.242%
Firm Entry			
Mean Number of Entry (Yearly)	889.897	889.437	890.177
Mean Number of State-owned Entrants (Yearly)	37.762	37.757	37.777
Mean Number of Private Entrants (Yearly)	852.134	851.680	852.400

Table 2.12: Statistics of Simulated Markets (Reform Selection on Firm Productivity)

Statistics	Selection on Productivity	No Selection
TFP Improvement		
Mean (Weighted) Industry TFP	0.302	0.301
Mean (Weighted) TFP of SOEs	0.230	0.213
Mean (Weighted) TFP of Private Firms	0.308	0.307
TFP Percentage Differences Between Private and State-owned firms	34.219%	44.173%
Mean (Weighted) TFP of Privatized SOEs Before Privatization	0.248	0.164
Mean (Weighted) TFP of Privatized SOEs After Privatization	0.344	0.282
TFP Improvements from SOEs to Private Firms	39.058%	74.955%
Correlation Between Capital and TFP	0.424	0.429
Physical Capital		
Industry Mean Capital Value (Thousands)	181.934	169.269
Mean Capital Value of SOEs (Thousands)	187.562	92.080
Mean Capital Value of Private Firms (Thousands)	181.424	176.935
Privatization		
Number of Observations	52052	50972
Number of State-owned Observations	4167	3467
Number of Private Observations	47886	47504
Sample Size of Privatized SOEs Before Privatization	221	125
Sample Size of Privatized SOEs After Privatization	700	399
Percentage of SOEs Privatized	12.191%	7.082%
Mean Privatization Rate (Yearly)	2.018%	1.256%
Firm Turnover		
Mean Exit Rate (Yearly)	3.963%	4.476%
Mean SOEs Termination Rate (Yearly)	12.628%	22.324%
Mean Private Firm Exit Rate (Yearly)	3.312%	3.315%
Firm Entry		
Mean Number of Entry (Yearly)	889.897	888.177
Mean Number of State-owned Entrants (Yearly)	37.762	37.689
Mean Number of Private Entrants (Yearly)	852.134	850.488

Table 2.13: Statistics of Simulated Markets (Separate Channels of Reform)

Statistics	Entry and Reform	Reform Only	Entry Only
TFP Improvement			
Mean (Weighted) Industry TFP	0.302	0.316	0.295
Mean (Weighted) TFP of SOEs	0.230	0.217	0.208
Mean (Weighted) TFP of Private Firms	0.308	0.339	0.308
TFP Percentage Differences Between Private and State-owned firms	34.219%	56.197%	48.290%
Mean (Weighted) TFP of Privatized SOEs Before Privatization	0.248	0.242	N/A
Mean (Weighted) TFP of Privatized SOEs After Privatization	0.344	0.333	N/A
TFP Improvements from SOEs to Private Firms	39.058%	38.192%	N/A
Correlation Between Capital and TFP	0.424	0.545	0.417
Physical Capital			
Industry Mean Capital Value (Thousands)	181.934	500.243	175.395
Mean Capital Value of SOEs (Thousands)	187.562	284.461	168.144
Mean Capital Value of Private Firms (Thousands)	181.424	575.439	176.484
Privatization			
Number of Observations	52052	16560	54166
Number of State-owned Observations	4167	3293	6929
Number of Private Observations	47886	13266	47236
Sample Size of Privatized SOEs Before Privatization	221	252	0
Sample Size of Privatized SOEs After Privatization	700	612	0
Percentage of SOEs Privatized	12.191%	17.824%	0%
Mean Privatization Rate (Yearly)	2.018%	2.030%	0%
Firm Turnover			
Mean Exit Rate (Yearly)	3.963%	3.303%	2.779%
Mean SOEs Termination Rate (Yearly)	12.628%	7.023%	0%
Mean Private Firm Exit Rate (Yearly)	3.312%	2.444%	3.307%
Firm Entry			
Mean Number of Entry (Yearly)	889.897	0	890.943
Mean Number of State-owned Entrants (Yearly)	37.762	0	37.787
Mean Number of Private Entrants (Yearly)	852.134	0	853.157

Chapter 3

State-owned Enterprises Reform and Productivity: A Case Study of China

3.1 Introduction

In 1978, designed and Guided by Deng, Xiaoping, China adopted the twin policies of opening its door to foreign trade and investment, and reforming its state-owned enterprises (SOEs). It has been more than thirty years since the adoption of these two policies and the "open door" policy had been recognized as very successful and made China the world's second largest economy by nominal GDP and by purchasing power parity after the United States. On the other hand, the state-owned-enterprise reforming did not show a spectacular progress comparing to the "open door" policy. China has taken a gradual and selective approach towards privatization mainly because, in addition to profit making, another important goal of China's SOEs is to absorb surplus labor. Policies makers worried that drastic privatization of large SOEs will rise unemployment quickly and bring China unstable economic as well as political environment. Even though Chinese government has been very conservative on performing SOE reforms, the speed of reforming was still fast enough to distinguish China from other formerly centrally planned economies. Therefore, China is a very interesting case to study the effects of privatization and other related SOE reforms.

There were many economic and political literatures focus on China's privatization process. one of the most relevant one is Bai et al., (2009) which investigated the effects of privatization on social welfare and firm performance indicators using the data from annual surveys of manufacturing and mining firms conducted by the national Bureau of statistics of China for the period of 1998 to 2005. They used three sets of indicators: (1) social welfare indicators on labor, consumers and governments, (2) indicators on firm performance, and (3) individual components of the operating income to sales. They found that privatizing China's SOEs led to increasing sales and more productive labor. In addition, there was a gain in firms' profitability.

As in Bai et al., (2009), our paper also studies the impacts of China's privatization process, however with a different approach. Bai et al., (2009) uses sale per labor as a measure of labor productivity and there is no indicator that can be considered as a measure of capital productivity. In fact, ignoring capital productivity is a big pitfall since SOEs are relatively bigger in size because of government's preferential policies. How SOE reform works on capital allocation and efficiency can not be overlooked. Therefore we instead focus on firms' total factor productivity (TFP) by estimating their production function using the method proposed by Olley and Pakes (1996) and Levinsohn and Petrin (2003). The second main difference of our paper from Bai et al., (2009), is that we carry out the analysis for each industries separately. The reason is that firms in different industries can behave very differently because they compete in different market structures. Therefore, their responds to the reform may also be very different.

Once a measure of TFP for each firm is found, we carry out the following three analyses. (1)We look at each industry's aggregate TFP and investigate whether there is an improvement in overall efficiency. (2)We follow Olley and Pakes (1996) to decompose industry level aggregate TFP into two parts, firms' average productivity and output allocation, and ask if the improvement in TFP (if any) can be attributed to more efficient market output allocation. (3)We are interested in comparing TFP between SOEs and private firms.(4) We use difference in difference model to study the role played by SOE reform in firms' TFP changes.

Our results show that improvements in aggregate TFP for all industries in China. These growths in productivity were resulted from enterprises becoming more productive, but not from more efficient output allocation in the market. Private firms were proven to be more productive than state-owned enterprises in all industries, but privatization itself improved firms efficiency only for some industries.

The structure of the paper is as follows. In Section 3.2, we describe our samples constructed from the annual surveys of manufacturing and mining firms, and offer some summary statistics of the data. The econometric method used for analysis is offered in Section 3.3, and the results of econometric analysis are presented in Section 3.4. Section 3.5 concludes.

3.2 Data and Statistics

Our data set is the Chinese Industrial Enterprises Database extracted and reorganized from the annual surveys of manufacturing and mining firms conducted by the National Bureau of Statistics of China. The target firms of this database include all state-owned enterprises and non-state-owned enterprises with an annual sale of products higher than 5 million RMB (approximately 782,000 US dollars). The sample period is from 1997 to 2006.[1] This is a very comprehensive dataset in a sense that the number of firms covered in the surveys varied from approximately 162,000 to approximately 336,000, it includes enterprises from 32 different province-level divisions and more than 40 two digits industries, and, in addition, it reports hundreds of variables for each enterprises. All of the features above make this dataset one of the most important resources in economic and management researches in China.

[1]Even though 2007 data is also available, the lack of firm identification number makes this year very hard to use.

Using the unique firm identification number, we first construct an unbalanced panel data with enterprises that appear at least three consecutive years in our sample and have valid data entries[2]. This process gives us a sample of 276,057 enterprises and 1,502,916 observations in total. The sample is used to estimate the production function and calculate TFP for each firms. Once productivity measures are constructed and all productivity related questions are answered, we pick exclusively those enterprises that start as SOEs in our dataset, and use only those observation for further investigation on the effect of privatization. This step reduces our sample to 26,753 enterprises and 172,557 observations. Among these 26,753 enterprises, 7,446 of them are privatized and the rest maintains state ownership.

The variables we use for this study include legal person number (unique firm identification number), industry classification, industrial added value, fixed assets, average number of employees, location ID, opening date (opening year in specific), long term investment, and, of course, ownership and registration type. We construct measures of labor, capital, output, age and time by using average number of employees, total assets, industrial added value, opening year, and the survey year respectively. All value based variables (industrial added value, total assets, and long term investment) are discounted using industry specific producer price index (PPI) found in China's statistical year book.

Note that most of the missing and unreasonable values for ownership type are interpolated using the information available in other years for the same firms. For example, if an enterprise has never been state owned through out sample periods according to the available data, its missing ownership type is interpolated as privately owned. In other cases where missing ownership can't be figured out this way, we can use their registration type to find out their missing ownership type. We are very

[2]Hsieh and Song (2015) use the same dataset and decide to include only firms which appear at least three consecutive years for more accurate estimation. More details about data cleaning procedure can also be fount in Hsieh and Song(2015).

confident about the accuracy of this process since most of the cases are very similar to the case explained in the examples above. For the cases we are uncertain, we decide to delete those observations, but they are very few.

To interpolate missing and unreasonable location IDs and opening years, we used a technique refered to as “finding dominant values”. Specifically, when there are different location IDs or opening years for the same firm, we find out the dominant value (or the most frequently appeared value) and use this value for the missing ones. Since it is very rare for enterprises to change locations, we believe the way we deal with location ID is satisfactory. Similarly, birth year will never change for a firm and different open years must simply be a typo. Therefore, our “finding dominant values” method should work well enough. In addition, the number of missing values is relatively small. As usual, we delete all firms which give us a hard time to interpolate those information. We also delete all firms with zero or negative average number of employees, long term investment, total assets or industrial added value. The process deletes very few firms.

Variable creation is fairly standard for this study except the construction of a real capital measure. In specific, it is difficult to build real capital measure for the following two reasons. First, firms only report the value of their fixed capital stock at the original purchase prices. Therefore, considering fixed assets as a measure of capital without any adjustment would be problematic. Second, firms do not report their fixed investment. So the standard perpetual inventory method can not be applied directly. In order to solve these two problems and build real capital correctly, we follow the approach proposed by Brandt, Biesebroeck & Zhang (2012) in which they developed a procedure that converts estimates at original purchase prices into real values that are comparable across time and firms.[3]

[3]The details of this procedure can be found in the appedix, section 3.6.1, as well as in Brandt, Biesebroeck & Zhang (2012).

3.2.1 Basic Summary Statistics

Table 3.1 provides us some basic information of our underlying firm level dataset. The table shows average value of some most relevant variables over sample years. Firstly, we notice that the sample size increases over years from 84,880 firms in 1998 to about 200,000 firms at the end of sample period. On average, added industrial value, gross output value, net fixed asset and Intermediate Input values rises gradually over time, that is consistent with the fact that China's economic had been growing during those years. It is interesting that, as time goes by, the average firm hires less and less employees (from 431.21 in 1998 to 284.05 in 2007). This might be a byproduct of privatization, as we know from the introduction that one social function of SOEs is to hire access among of employees in order to keep unemployment rate low and help government to achieve economic and political stability. Once privatized, those firms focused only on profit maximization and started to lay off redundant workers. Another possible reason for firms hiring less workers over time could be that potential private entrants started to enter the market and compete, and those starters were relatively small.

A more important statistic to our study is to how many firms are actually reformed and how many percent of firms with different ownership types exist in the market over years. In table 3.2, we list the percentage of enterprises by registration type over our sample periods. As expected, the percentage of SOEs and collective enterprises decrease over years. Instead, the percentage of private firms grows dramatically from only 7.58% in 1998 to more than 50% in 2007 as public owned firms take a smaller proportion. One interpretation for such a drastic change is that SOEs go through reform and are privatized. The other interpretation is that a lot more private firms enter the market in later years, but there are very few state-owned entrants. We believe that both interpretations explained above are responsible and the structure of the market has changed dramatically during that period of time. To see this more clearly, we plot a bar chart showing the proportion of firms by registration type. In figure 3·1, the proportion of private firms (yellow bars) grows a lot replacing that of collective firms (light blue bars) and SOEs (dark blue bars). In addition, the proportion of foreign firms (red bars) stays almost intact over years.

Now we show some evidences for the achievement of China's SOE reform. Our panel sample covers 39 two-digit industries and 31 province level districts. Table 3.3 and Table 3.4 present the distribution of privatization by two-digit industries and by provinces respectively. The number of SOEs is the number of enterprises that are state-owned the first time they appear in the sample. The number of reformed are the total number of SOEs that undergoes reform during sample period. The percentage reformed is the ratio of the number of reformed SOEs (column 4) to the total number of SOEs (column 3). In both Table 3.3 and Table 3.4, the rows are sorted according to the percentage of reformed SOEs in descending order. In total, our panel dataset includes 26,753 SOEs as in 1998. Up to 2007, 7,446 of them (27.83%) are reformed. 27.83% is not a small number given only ten years. The speed of reform in China is in fact much faster than some other countries which adopt similar policies. On the other hand, even though 27.83% of SOEs are privatized, there are still many SOEs controlled by government.

There are more than 20,000 enterprises for textile industry (23,444 firms) and non-metal mineral products (21,589 firms). Their percentages of privatization are 39.36% and 35.18% respectively. Among 39 industries, Medical and Pharmaceutical Product, Smelting and Pressing of Nonferrous Metals, Smelting and Pressing of Ferrous Metals, Ferrous Metal Mining and Dressing, and Chemical Fiber Production undertake a dramatic privatization and more than 40% of SOEs are reformed in these industries. Notice that many of these top five reformed industries involves metals. It is surprising to see Medical and Pharmaceutical Products industry having such a high level of privatization since this industry is usually strictly supervised and regulated by governments. On the other hand, Production and Supply of Tap Water (10.11%), Printing and Record Medium Reproduction (13.81%), and Production and Supply of Power, Steam and Hot Water (15.62%) stay at the bottom of Table 3.3. Even though Tobacco Processing (11.52%), Other Minerals Mining and Dressing (0%) and Waste Resources and Material Recycling (0%) also have very low privatization percentage, our sample contains very few firms in these industries (less than 300 firms). Therefore, there is not enough information for us to discuss these industries in details.

Table 3.4 shows the distribution of privatization by locations. In specific, we break our sample into sub-samples according to province-level districts and our sample covers all province-level districts in China main land (31 in total). The province-level districts include not only regular provinces, but also municipalities directly under the central government and autonomous administrative divisions. Jilin province have the highest percentage of privatization (46.51%), followed by Jiangsu (45.37%), Shandong (39.7%), and Anhui (39.39%) provinces. The least privatized provinces are Tibet (8.2%), Hainan (12.28%), Guizhou (13.51%), Tianjin (16.28%) and Guangxi (16.3%) provinces. In general, we see relatively rich provinces stay on top of the list and relatively poor provinces stick around the bottom of the table. As stated in Bai et al., (2009) that privatized firms on average enjoy a higher profit margin, we are not surprised to see such correlation between privatization and GDP. However, this table does not tell us whether privatization is the cause for better economic condition because it can also be the case that relatively richer provinces are more likely to undergo drastic privatization. We will investigate this question in details in later sections.

3.3 Estimation of Production Function and Productivity

Previous subsection provides a broad view of China's recent economic reform. In this section, we estimate production function using the method proposed by Levinsohn & Petrin (2003) and calculate productivity for each firm. Once we have the estimates of productivity measures, we will investigate productivity related questions in the following sections. Different from Brandt, Biesebroeck & Zhang (2012), we estimate a distinct production function for each industry because industries work very differently from each other and our estimates should unfold such differences.

3.3.1 Production Function

Production function estimation suffers from the difficulty caused by simultaneity problem, a contemporaneous correlation between input (capital and labor) and error term. Simple OLS only offers biased estimates and the sign of the biases are undetermined. Fixed effect estimators offer more protection from this problem but may not be enough either. In order to perform this task well, we follow the method proposed by Olley & Pakes (1996) and Levinsogn & Petrin (2003). In fact, we are using the method proposed by Levinsogn & Petrin (2003) (LP) which is a variety of method originated by Olley & Pakes (1996). We can't apply Olley & Pakes (1996) directly because they use investment as a proxy but valid investment information is often not available for developing countries and China is no exception. Fortunately, Levinsogn & Petrin (2003) utilizes intermediate inputs value as a proxy which is observable for Chinese firms.

We assume that the production function for firm i at time t follows a usual Cobb-Douglas functional form,

$$\begin{aligned} y_{it} &= \beta_0 + \beta_l l_{it} + \beta_k k_{it} + \varepsilon_{it} \\ \Longrightarrow y_{it} &= \beta_0 + \beta_l l_{it} + \beta_k k_{it} + \omega_{it} + \eta_{it}, \end{aligned} \tag{3.1}$$

where y_{it} is its logged added value, l_{it} and k_{it} are its logged labor and capital, ω_{it} is a transmitted component, and η_{it} is an iid component. The problem with estimating equation (3.1) using OLS is that ω_{it} (as well as ε_{it} because $\varepsilon_{it} = \omega_{it} + \eta_{it}$) is correlated with factors of production, capital and labor. To deal with the issue, we assume intermediate input demand function is

$$\tau_{it} = \tau(\omega_{it}, k_{it}).$$

By assuming τ_{it} is monotonic in ω_{it} for all k_{it}, we can invert the intermediate input demand function,

$$\omega_{it} = \omega(\tau_{it}, k_{it}).$$

Then we try to identify the coefficient β_l and β_k with a two steps procedure. In step 1, we figure out an unbiased estimate of the coefficient for labor, $\hat{\beta}_l$. In step 2, we estimate the coefficients for capital, $\hat{\beta}_k$, using GMM.

In specific, we rewrite equation (3.1) as

$$y_{it} = \beta_l l_{it} + \phi(\tau_{it}, k_{it}) + \eta_{it} \tag{3.2}$$

where

$$\phi(\tau_{it}, k_{it}) = \beta_0 + \beta_k k_{it} + \omega_{it}(\tau_{it}, k_{it}) \tag{3.3}$$

Then we regress y_{it} on τ_{it} and k_{it} using a 4th order polynomial and obtain an estimate of $E(y_{it}|\tau_{it}, k_{it})$. We also obtain an estimate of $E(l_{it}|\tau_{it}, k_{it})$ by running a similar regression of l_{it} on τ_{it} and k_{it}. Subtracting expected output from production function (3.2) offers the following equation,

$$y_{it} - E(y_{it}|\tau_{it}, k_{it}) = \beta_l(l_{it} - E(l_{it}|\tau_{it}, k_{it})) + \eta_{it}, \tag{3.4}$$

which can be estimated without bias to get $\hat{\beta}_l$. This concludes the first stage of my estimation method.

In stage 2, we can transform equation (3.2) into the following form,

$$\begin{aligned} y_{it} - \hat{\beta}_l l_{it} &= \beta_0 + \beta_k k_{it} + \omega_{it} + \eta_{it} \\ \Longrightarrow y_{it} - \hat{\beta}_l l_{it} &= \beta_0 + \beta_k k_{it} + E(\omega_{it}|\omega_{it-1}) + \xi_{it} + \eta_{it}, \end{aligned} \tag{3.5}$$

where

$$\xi_{it} = \omega_{it} - E(\omega_{it}|\omega_{it-1}).$$

Notice that $y_{it} - \hat{\beta}_l l_{it} = \phi(\tau_{it}, k_{it}) + \eta_{it}$. So we can obtain an estimate of ϕ_{it} by running a regression of $y_{it} - \hat{\beta}_l l_{it}$ on τ_{it} and k_{it} with a 4th order polynomial. Let's denote the estimates as $\hat{\phi}_{it}$.

Then we carry out the following steps.

1. We pick candidate values for β_0 and β_k, and let's call them β_0^* and β_k^* respectively.

2. Calculate $A = \omega_{it} \hat{+} \eta_{it} = y_{it} - \beta_0^* - \hat{\beta}_l l_{it} - \beta_k^* k_{it}$, by equation (3.1).

3. Calculate $B = \hat{\omega_{it-1}} = \hat{\phi}_{it-1} - \beta_0^* - \beta_k^* k_{it-1}$, by equation (3.3).

4. We regress A on B with a 4th order polynomial to obtain an estimate of $E(\omega_{it}|\omega_{it-1})$, $\hat{E}(\omega_{it}|\omega_{it-1})$.

5. Compute $\eta_{it}^* = \xi_{it} + \eta_{it} = y_{it} - \hat{\beta}_l l_{it} - \beta_0^* - \beta_k^* k_{it} - \hat{E}(\omega_{it}|\omega_{it-1})$ according to equation (3.5).

6. GMM can be calculated using the following equation

$$GMM(\beta_0^*, \beta_k^*) = \sum_h (\sum_i \sum_t (\eta_{it}^*(\beta_0^*, \beta_k^*) \cdot Z_{hit}))^2$$

   where $Z_{it} = \{k_{it}, \tau_{it-1}, l_{it-1}, k_{it-1}, \tau_{it-2}\}$ and h is the index for elements in vector Z.

7. Go back to step 1 and choose another set of β_0^* and β_k^*, and then recalculate variables from step 2 through step 6. We keep doing the steps above until GMM is minimized, and β_0^* and β_k^* which achieves the minimal GMM are our estimates, $\hat{\beta}_0$ and $\hat{\beta}_k$ respectively.

This completes the description of our estimation method and all parameters of production function, $\hat{\beta}_0$, $\hat{\beta}_l$, and $\hat{\beta}_k$ are estimated.

3.3.2 Productivity

Once we have estimated the parameters in production function, we can calculate each firm's productivity as residual using the equation,

$$\varepsilon_{it} = y_{it} - \hat{\beta}_0 - \hat{\beta}_l l_{it} - \hat{\beta}_k k_{it} \tag{3.6}$$

3.4 Results

In this section, we present our main results. We start with the estimated parameters of production functions, and show you how Productivity evolves in China during our sample periods. Then we practice a productivity decomposition proposed by Olley and Pakes (1996) to investigate whether productivity changes are related to industries' output reallocation. Finally, we present our difference in difference results on whether China's SOE reform play a significant role in firms' efficiency gain.

3.4.1 Estimated Production Function

In Table 3.5, We show the results of our production function estimation. In addition to the results from using the LP method, we also present the results from three additional models for comparisons, (1) simple OLS, (2) OLS with firm fixed effect to deal with unobserved firm specific features, (3) OLS with firm and time fixed effect to further account for macro economics changes. In general, OLS overestimates coefficients $\hat{\beta}_l$ and $\hat{\beta}_k$ for almost all industries. By adding firm fixed effect, the coefficients are corrected downwards by a lot. It seems like that the dependent variables (capital and labor) are positively correlated with unobserved factors that affect output. In fact, this confirms our expectation that more productive firms find themselves more profitable by producing more outputs, which increase their uses of production factors (capital and labor). The firm fixed effect method provides some protection from this endogenous problem. The model with both firm and time dummy offers similar results from the one with firm dummy only. Therefore we claim that the effects of macro economics environment changes on a firm's output is limited. Note that Levinsogn & Petrin (2003) (LP) method adjusts $\hat{\beta}_l$ downwards but $\hat{\beta}_k$ upwards for almost all industries compared to our two fixed effect models. Without LP adjustment, the estimate of labor coefficient is much larger than that of capital coefficient. This is saying that labor is much more important than capital in production process. However, LP method shrinks the gap between these two numbers. We bootstrap the standard error of LP model with 100 samples selected from original dataset with replacement. The standard errors for all models are reported in parenthesis below each estimates. The regression results of all industries and of all models are significantly different from zero.

3.4.2 Productivity Growth

To see how Productivity evolves in China during our sample periods, we calculate each firm's productivity using equation (3.6) as well as the estimates from LP model presented above. We then aggregate firms' productivity to find an efficiency measure for each industry. We first calculate the weighted average productivity for each industry at each year using firms' market share (measured by output level) as weights. Table 3.6 reveals such information with each entry representing the annual growth rate of weighted average productivity for the corresponding industry and sample year. In general, even though the weighted average productivities for most industries go up and down all the time, they increase hermetically within years. Howeverm some industries growing faster than others.

In order to compare productivity growth among industries, we normalize the weighted average in 1997 (our starting sample year) to be 1. To make our comparison easier, we selected only 5 representative industries and draw a bar chart for their productivity measures. The selected industries are Textile Industry, Nonmetal Mineral Products, Raw Chemical materials and Chemical Products, Production and Supply of Tap Water, Medical and Pharmaceutical Product, and Ordinary Machinery. Figure 3·2 represents the weighted average productivity (normalized) in each sample years for these industries. As can be seen, our productivity measures for all these industries start with 1 in 1997 and continuously rising through out our sample periods. Textile Industry shows the most impressive improvement in efficiency among these industries and its average productivity in 2006 is about 6.5 times more than that in 1997.

3.4.3 Productivity Decomposition

In addition to output weighted average productivities, we can also practice a productivity decomposition proposed by Olley and Pakes, (1996). In specific, we can separate weighted average productivity into (1) unweighted average productivity and (2) a term related to correlation between market share and productivity. Mathematically, the decomposition can be written as

$$\begin{aligned} P_t &= \sum_{i=1}^{N_t} S_{it} P_{it} = \sum_{i=1}^{N_t} (\bar{S}_t + \Delta S_{it})(\bar{P}_t + \Delta P_{it}) \\ &= N_t \bar{S}_t \bar{P}_t + \sum_{i=1}^{N_t} \Delta S_{it} \Delta P_{it} = \bar{P}_t + \sum_{i=1}^{N_t} \Delta S_{it} \Delta P_{it}, \end{aligned} \tag{3.7}$$

where P_t is market share weighted average productivity for an industry at time t, S_{it} and P_{it} are market share and productivity for firm i at time t, $\bar{S}_t$ and $\bar{P}_t$ denote unweighted average market share and productivity at time t, and, in addition, $\Delta S_{it} = S_{it} - \bar{S}_t$ and $\Delta P_{it} = P_{it} - \bar{P}_t$ are deviations of market share and productivity from their corresponding mean. This equation is applied to all industries individually and we omit industry subscript here for easy representation. According to this equation, there can be two sources of rising productivity: (1) increased productivity of each individual firm on average, and (2) more efficient market allocation with more productive firms producing more industry outputs.

To convey the idea more efficiently, we omit long tables containing information for all industries and plot a bar chart only for the 5 representative industries selected in the previous subsection. Figure 3·3 reveals the growths of unweighted average productivity for these industries. All of them increase over time, similar to the overall behavior of market share weighted averages presented in Figure 3·2. However, unweighted average productivities change less dramatically compared to their weighted counter part, which tells us the impressive growth shown in igure 3·2 being largely driven by the second term of the decomposition. This conjecture is confirmed by Firgure 3·4 in which we plot growths of the second term in equation (3.7) for these industries. As expected, these measures increase over time for all industries selected and Textile Industry is again the winner among five selected industries with an increase of more than six times within ten years.

Let's now focus on the second part of our productivity decomposition which is $\sum_{i=1}^{N_t} \Delta S_{it} \Delta P_{it}$ in equation (3.7) above. Technically, this is not the covariance between market share and productivity if not dividing it by the number of firms in the industry. The correct covariance should be written as $\frac{1}{N_t} \sum_{i=1}^{N_t} \Delta S_{it} \Delta P_{it}$. To differentiate this term from real covariance, we call it "the covariance between market share and productivity without market size adjustment", as in the caption of Figure 3·4.

This observation suggests that the increase in $\sum_{i=1}^{N_t} \Delta S_{it} \Delta P_{it}$ over years has two possible sources: (1) more efficient market allocation and (2) more firms in the market or larger market size. In order to find out which is the main driving force, we calculate the real covariances and their corresponding correlation coefficients. In Figure 3·5, we plot the correlation coefficients which not only take into account the effects of market size but also normalize variances. We do not see more efficient market reallocation among five selected industries in this figure. In fact, this is also the case for all other industries which are not shown in this figure. The conclusion we arrive from decomposing weighted average productivity is that the increases in weighted average productivity in China can be explained by increased productivity of each individual firms on average and larger market size, but little can be explained by more efficient allocation of production within markets.

3.4.4 The Effects of Reform

In previous sections, we only discuss firms' productivity in China, but do not try to disentangle the relationship between productivity and China's economic reform. In this subsection, we switch gear and answer the question whether China's SOE reform plays a big role in its productivity growth. In order to do this properly, we delete six industries which either have less than 100 SOEs or do not experience privatization from our original sample. In this reduced dataset, we have 33 industries and 171,046 observations left. All these industries have more than 100 SOEs and all undergo reform to some extent.

There are two challenges that need our attentions when setting up regressions. First, we have to properly control for those unobserved factors that are correlated with a firm's ownership and also essential for its productivity. Take labor quality for example. It has been noticed that SOEs attract very different types of workers from those working for private firms. Public firms in China are used to offer "Iron Rice Bowl", a term referring to an occupation with guaranteed job security, as well as steady income and benefits. Jobs in a SOE are certainly viewed as more secure and stable than those in private firms, and are attractive to some people even though similar jobs in private sectors pay more. Therefore, the most ambitious people, who happen to be more efficient, will choose to work for private firms, and people who enjoy stable and relaxed life style will be more likely to stay in a SOE. Hence, the quality of labor hired by SOEs is very different from that hired by private firms, and the quality of labor certainly affect productivity of the firm.

Second, privatization in China is a careful selection process. Instead of adopting a uniform reform policy for all SOEs, the governments decided to take conservative and gradual steps and experiment with policy on the smallest SOEs first before applying it to larger ones. This is the central idea of the policy called "grasp the large, let go of the small". In fact, when governments decide which firms to be privatized, their productivity is also an important factor to be considered in addition to their size. Generally speaking, for two SOEs of the same size, the more productive one is more likely to be privatized. Therefore, simple OLS may over estimate the effects of privatization on firms' productivity.

After a conprehensive consideration, we decide to use difference in differences model to investigate the effects of SOE reform on productivity. In specific, we consider the following four different model specifications. First, we use the simplest model with firm fixed effect,

$$P_{it} = \alpha_i + \tau R_{it} + \varepsilon_{it},$$

where R_{it} is the dummy variable indicating private ownership of firm i at time t and α_i is the firm fixed effect representing unobserved firm characteristics which affect productivity. Next, We use difference in differences model with the following specification,

$$P_{it} = \alpha_i + \lambda_t + \tau R_{it} + \varepsilon_{it}.$$

In this specification, we add time period dummies, λ_t. In the next model, we add control variables which are relevant to firms' productivity,

$$P_{it} = \alpha_i + \lambda_t + \tau R_{it} + X_{it}\gamma + \varepsilon_{it}.$$

The control variables used include firms' added value, labor, capital stock and labor cost. Finally, we not only control for relevant characteristics in current period, but also include characteristics in previous years,

$$P_{it} = \alpha_i + \lambda_t + \tau R_{it} + X_{it}\gamma + Z_{it-1}\theta + \varepsilon_{it}.$$

Table 3.7 presents the results from these regressions for all industries. In general, the results are mixed. The key estimate we are interested in is the effect of a firm's private ownership on its productivity. We find significant effects for only 9 out of 33 industries. 8 of them exhibit significant positive effect and only 1 shows significant negative effect. Even though we do not find significant results for the majority of industries, the sign of the coefficients for 21 industries are positive, which indicates that privatization increases firms' productivity. Therefore, our conclusion from this exercise is that, even though productivity has improved a lot in all industries in China during transformation, we can only attribute such productivity growths for some industries to China's SOE reform.

3.5 Conclusion

In this paper, we estimate a production function for each two-digits industry in China using the method proposed by olley and Pakes (1996) and Levinsohn and

Petrin (2003), and we calculate a measure of total factor productivity for each firm out of those estimates. We then look at how overall productivity evolved during our sample period (1997-2006), if such productivity improvement is related to more efficient output allocation, and whether the changes in productivity were related to the reform. We find improvements in average market productivities for all industries in China. These growths in productivity were resulted from enterprises becoming more productive, but not from more efficient output allocation within markets. Finally, we found that privatization improved firms efficiency only for some industries.

One drawback of this study is that the effects of privatization may not be immediate. Once SOEs change its ownership and management system, they may need time to adjust their production factors and their productivity may not be improved right away. Therefore, a model that investigate long term effects of privatization may be more appropriate. In addition, it is very interesting to look at the spillover effects of privatization. Firms becoming more efficient can be a result of not only changing their ownership but also facing more competitive environment. Therefore, the spillover effects may be significant and change the angle we view this question completely.

3.6 appendices

3.6.1 Construction of Real Capital

To explain the procedure of real capital construction proposed by Brandt, Biesebroeck and Zhang (2012) in a greater detail, we show it as a five step process. (1) We find the average fixed asset information in 1993 for each industries at each provinces and construct the total growth of nominal capital stock from 1993 to 1998 at the two-digit industry level for each provinces. We then calculate average nominal capital growth rate per year from 1993 to 1998 by simply assuming all years exhibit same growth rate. In addition, the yearly growth rate from 1998 to 2007 can be calculated directly because the data on those years are observable. (2) By discounting the fixed asset reported in the last available year using the growth rate calculated in step 1, we can derive the nominal capital for each firms at their birth year. (3) We use the information calculated from step 1 and 2 to obtain the nominal capital for each firms from their birth year to the last year in our dataset. (4) The difference between nominal capital measures in two consecutive years can be thought as the firm's nominal investment and real investment can be derived by price deflation using Brandt-Rawski deflater. (5) Finally, real capital stocks for each year are calculated using perpetual inventory method, $K_{it} = \sum_{\tau=0}^{\tau=t}(1-\delta)^{\tau} \times I_{i\tau}$, which means that the real capital of firm i at time t is the sum of all its real investments (depreciation are accounted for) from its birth year to current year.

Table 3.1: Summary Statistics of The Underlying Firm Level Data Set

Year	No. of Firms	Value Added	Gross Output	Employment	Net Fixed Asset	Intermediate Input
1997	84880	16.16	53.43	431.21	47.33	39.56
1998	94108	16.82	54.87	403.30	49.52	40.45
1999	106771	18.28	60.13	370.81	51.41	44.46
2000	115742	19.04	62.51	334.39	52.53	46.15
2001	127428	20.62	67.66	323.49	53.40	49.80
2002	144228	23.32	77.67	308.78	54.65	57.39
2003	199547	22.70	78.19	255.95	45.78	58.15
2004	219908	27.70	94.44	257.35	50.96	69.96
2005	211956	34.34	117.76	269.23	59.12	87.43
2006	198348	43.56	149.54	284.05	70.54	111.13

Notes: all values are average numbers and denoted in million RMB.
(except employment and number of firms).

Table 3.2: Percentage of enterprises by registration type

Year	No. of Firms	% SOEs	% Collective	% Private	% Foreign & HMT	% Other
1997	84880	26.76%	30.36%	7.58%	17.79%	17.51%
1998	94108	24.22%	28.28%	10.01%	18.34%	19.15%
1999	106771	20.62%	25.01%	14.31%	18.53%	21.54%
2000	115742	15.30%	18.78%	22.79%	19.58%	23.54%
2001	127428	12.46%	15.48%	28.66%	19.80%	23.59%
2002	144228	9.27%	11.61%	35.90%	20.12%	23.10%
2003	199547	5.84%	6.69%	44.91%	21.03%	21.53%
2004	219908	4.78%	5.80%	47.51%	20.45%	21.47%
2005	211956	4.41%	4.96%	49.21%	20.58%	20.85%
2006	198348	3.29%	4.43%	50.10%	21.09%	21.10%

Figure 3·1: Percentage of enterprises by registration type

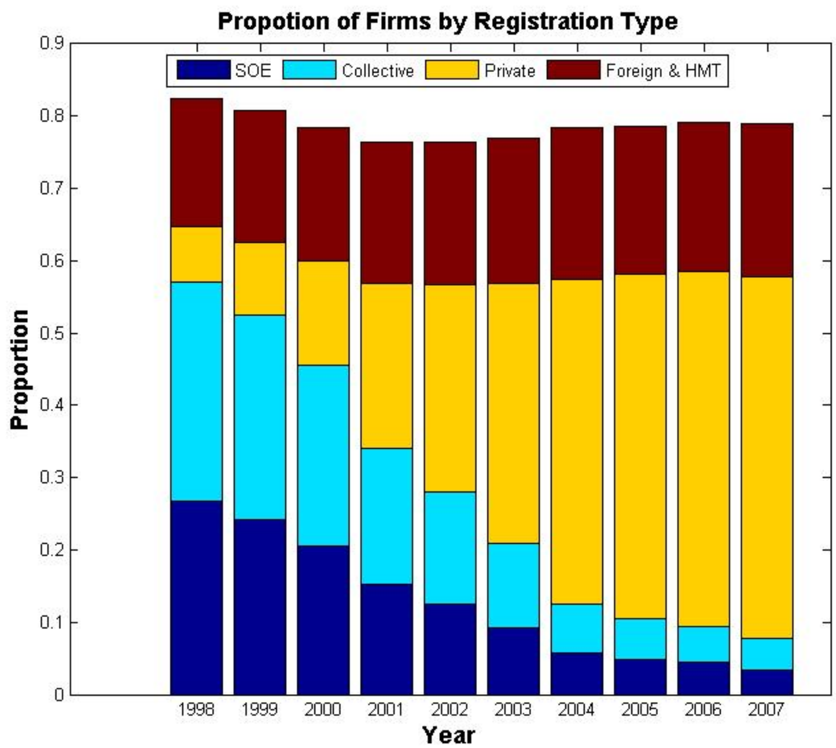


Table 3.3: Distribution of Reform by Industries

Industry	No. of Firms	No. of SOEs	No. of Reformed	Percentage Reformed
Medical and Pharmaceutical Products	4867	721	336	46.60%
Smelting and Pressing of Nonferrous Metals	4754	238	104	43.70%
Smelting and Pressing of Ferrous Metals	6423	303	132	43.56%
Ferrous Metal Mining and Dressing	1881	106	45	42.45%
Chemical Fiber Production	1247	47	19	40.43%
Textile Industry	23444	1034	407	39.36%
Raw Chemical Materials and Chemical Products	18676	1658	649	39.14%
Beverage Production	3998	769	300	39.01%
Petroleum Refining and Coking	1933	164	59	35.98%
Electric Equipment and Machinery	15255	742	265	35.71%
Electronic and Telecommunications	8041	379	135	35.62%
Nonmetal Mineral Products	21589	2163	761	35.18%
Rubber Products	3055	155	52	33.55%
Paper Making and Paper Product	7810	425	142	33.41%
Production and Supply of Gas	368	135	44	32.59%
Ordinary Machinery	19940	1534	487	31.75%
Leather, Furs, Down and Related Products	6457	98	30	30.61%
Instruments, Meters, Cultural and Clerical Machinery	3412	337	97	28.78%
Metal Products	14066	495	142	28.69%
Special Purpose Equipment	10341	1273	360	28.28%
Food Processing	15627	2443	686	28.08%
Coal Mining and Processing	5410	958	269	28.08%
Textile Clothing, Shoes, Hats Production	12751	251	69	27.49%
Cultural, Educational and Sports Goods	3428	66	18	27.27%
Nonferrous Metal Mining and Dressing	1738	311	84	27.01%
Food Production	5868	930	247	26.56%
Transport Equipment	11135	1397	366	26.20%
Petroleum and Natural Gas Extraction	155	47	12	25.53%
Logging and Transport of Timber and Bamboo	5558	249	59	23.69%
Nonmetal Mining and Dressing	2709	386	91	23.58%
Plastic Products	12305	353	79	22.38%
Handicraft and Other Manufacturing	5517	177	31	17.51%
Furniture Manufacturing	3099	111	19	17.12%
Production and Supply of Power, Steam and Hot Water	5057	2901	453	15.62%
Printing and Record Medium Reproduction	5244	1405	194	13.81%
Tobacco Processing	262	165	19	11.52%
Production and Supply of Tap Water	2342	1820	184	10.11%
Other Minerals Mining and Dressing	15	6	0	0.00%
Waste Resources and Material Recycling	280	1	0	0.00%
total	276057	26753	7446	27.83%

Table 3.4: Distribution of Reform by Provinces

Province	No. of Firms	No. of SOEs	No. of Reformed	Percentage Reformed
Jilin	1800	129	60	46.51%
Jiangsu	36580	1816	824	45.37%
Shandong	27933	1826	725	39.70%
Anhui	6039	726	286	39.39%
Inner Mongolia	2494	534	200	37.45%
Ningxia	662	128	46	35.94%
Zhejiang	41749	922	330	35.79%
Chongqing	3287	420	141	33.57%
Sichuan	7744	948	303	31.96%
Hubei	7817	1522	486	31.93%
Yunnan	2418	740	236	31.89%
Hebei	10216	1394	416	29.84%
Qinghai	405	159	47	29.56%
Shanxi	4347	903	264	29.24%
Shanghai	13947	814	214	26.29%
Guangdong	36655	1939	505	26.04%
Henan	11530	1202	310	25.79%
Heilongjiang	3163	851	200	23.50%
Hunan	8977	1549	359	23.18%
Shenyang	10653	1098	241	21.95%
Gansu	1874	115	25	21.74%
Jiangxi	5011	1376	274	19.91%
Shanxi	3229	936	181	19.34%
Xinjiang	1744	752	140	18.62%
Beijing	5979	1216	222	18.26%
Fujian	9995	221	38	17.19%
Guangxi	3851	1190	194	16.30%
Tianjin	3022	301	49	16.28%
Guizhou	2222	733	99	13.51%
Hainan	475	171	21	12.28%
Tibet	239	122	10	8.20%
total	276057	26753	7446	27.83%

Table 3.5: Estimation Results of Production Function

Industry	ID	Coef	OLS	Firm Fixed Effect	Firm+ Time Fixed Effect	LP
Coal Mining and Processing	6	β_l	0.2586 (0.0068)***	0.3985 (0.0116)***	0.3688 (0.0109)***	0.0723 (0.0166)***
		β_k	0.4083 (0.0053)***	0.1110 (0.0057)***	0.0602 (0.0054)***	0.1924 (0.0218)***
		NOO	28159	22749	22749	28159
Petroleum and Natural Gas Extraction	7	β_l	0.4021 (0.0337)***	0.5293 (0.0613)***	0.4031 (0.0603)***	-0.0758 (0.0205)***
		β_k	0.5774 (0.0247)***	0.1593 (0.0290)***	0.1190 (0.0279)***	0.1490 (0.0199)***
		NOO	813	658	658	813
Ferrous Metal Mining and Dressing	8	β_l	0.4580 (0.0125)***	0.4499 (0.0212)***	0.3939 (0.0197)***	0.1126 (0.0192)***
		β_k	0.2640 (0.0091)***	0.1490 (0.0116)***	0.0941 (0.0109)***	0.3430 (0.0497)***
		NOO	8594	6713	6713	8594
Nonferrous Metal Mining and Dressing	9	β_l	0.3672 (0.0132)***	0.3132 (0.0194)***	0.2854 (0.0180)***	0.1059 (0.0168)***
		β_k	0.2786 (0.0095)***	0.1085 (0.0099)***	0.0747 (0.0093)***	0.1557 (0.0180)***
		NOO	9334	7596	7596	9334
Nonmetal Mining and Dressing	10	β_l	0.4208 (0.0090)***	0.3032 (0.0146)***	0.3038 (0.0141)***	0.1539 (0.0187)***
		β_k	0.2170 (0.0063)***	0.0821 (0.0080)***	0.0657 (0.0078)***	0.1460 (0.0280)***
		NOO	13853	11144	11144	13853
Other Minerals Mining and Dressing	11	β_l	0.0858 (0.1406)	-0.2544 (0.1012)**	-0.2229 (0.1056)**	-0.0514 (0.0130)***
		β_k	0.3070 (0.0862)***	0.0536 (0.0914)	0.0383 (0.1035)	0.2777 (0.0098)***
		NOO	77	62	62	77
Food Processing	13	β_l	0.5036 (0.0049)***	0.3214 (0.0073)***	0.2971 (0.0071)***	0.1115 (0.0233)***
		β_k	0.2624 (0.0034)***	0.1033 (0.0042)***	0.0817 (0.0041)***	0.1816 (0.0371)***
		NOO	80387	64760	64760	80387
Food Production	14	β_l	0.5919 (0.0079)***	0.2997 (0.0108)***	0.2859 (0.0106)***	0.0997 (0.0224)***
		β_k	0.3439 (0.0053)***	0.0902 (0.0064)***	0.0751 (0.0063)***	0.1244 (0.0224)***
		NOO	31607	25739	25739	31607
Beverage Production	15	β_l	0.5699 (0.0091)***	0.3249 (0.0133)***	0.3153 (0.0130)***	0.1438 (0.0176)***
		β_k	0.3565 (0.0060)***	0.0762 (0.0077)***	0.0662 (0.0076)***	0.1191 (0.0269)***
		NOO	21941	17943	17943	21941
Tobacco Processing	16	β_l	0.9573 (0.0318)***	0.3378 (0.0448)***	0.3515 (0.0446)***	0.1689 (0.0210)***
		β_k	0.4926 (0.0192)***	0.1153 (0.0268)***	0.1018 (0.0268)***	0.1850 (0.0184)***
		NOO	1758	1496	1496	1758

Note: * 10% significant, ** 5% significant, *** 1% significant.

Table 3.5: Estimation Results of Production Function (Continued)

Industry	ID	Coef	OLS	Firm Fixed Effect	Firm+ Time Fixed Effect	LP
Textile Industry	17	β_l	0.4720 (0.0028)***	0.3645 (0.0053)***	0.3570 (0.0052)***	0.1732 (0.0153)***
		β_k	0.2521 (0.0020)***	0.1006 (0.0030)***	0.0784 (0.0029)***	0.1581 (0.0312)***
		NOO	125443	101999	101999	125443
Textile Clothing, Shoes, Hats Production	18	β_l	0.5732 (0.0043)***	0.3529 (0.0066)***	0.3494 (0.0066)***	0.2273 (0.0199)***
		β_k	0.2156 (0.0028)***	0.1009 (0.0038)***	0.0858 (0.0038)***	0.1542 (0.0260)***
		NOO	69174	56423	56423	69174
Leather, Furs, Down and Related Products	19	β_l	0.4984 (0.0053)***	0.3903 (0.0089)***	0.3795 (0.0088)***	0.1822 (0.0177)***
		β_k	0.2496 (0.0039)***	0.0909 (0.0051)***	0.0754 (0.0050)***	0.1381 (0.0284)***
		NOO	34850	28393	28393	34850
Logging and Transport of Timber and Banboo	20	β_l	0.5239 (0.0074)***	0.3583 (0.0114)***	0.3306 (0.0110)***	0.1572 (0.0213)***
		β_k	0.2238 (0.0044)***	0.0990 (0.0062)***	0.0780 (0.0060)***	0.1957 (0.0509)***
		NOO	26803	21245	21245	16803
Furniture Manufacturing	21	β_l	0.6158 (0.0092)***	0.4311 (0.0150)***	0.3938 (0.0148)***	0.1602 (0.0198)***
		β_k	0.2157 (0.0062)***	0.1146 (0.0083)***	0.0929 (0.0081)***	0.1541 (0.0199)***
		NOO	16049	12950	12950	16049
Papermaking and Paper Product	22	β_l	0.5029 (0.0060)***	0.3365 (0.0098)***	0.3254 (0.0096)***	0.1667 (0.0186)***
		β_k	0.3056 (0.0038)***	0.1017 (0.0054)***	0.0859 (0.0053)***	0.1387 (0.0270)***
		NOO	43195	35385	35385	43195
Pringting and Record Medium Reproduction	23	β_l	0.4906 (0.0080)***	0.3329 (0.0117)***	0.3240 (0.0117)***	0.1685 (0.0209)***
		β_k	0.4641 (0.0049)***	0.0957 (0.0068)***	0.0882 (0.0068)***	0.1442 (0.0225)***
		NOO	29696	24452	24452	29696
Cultural, Educational and Sports Goods	24	β_l	0.5257 (0.0068)***	0.3505 (0.0127)***	0.3472 (0.0125)***	0.2112 (0.0174)***
		β_k	0.2201 (0.0048)***	0.0740 (0.0072)***	0.0554 (0.0071)***	0.0869 (0.0266)***
		NOO	19257	15829	15829	19257
Petroleum Refining and Coking	25	β_l	0.4742 (0.0126)***	0.4904 (0.0234)***	0.4672 (0.0225)***	0.1568 (0.0213)***
		β_k	0.3878 (0.0082)***	0.1111 (0.0116)***	0.0750 (0.0113)***	0.1789 (0.1742)
		NOO	9915	7982	7982	9915
Raw Chemical Materials and Chemical Products	26	β_l	0.3758 (0.0038)***	0.3535 (0.0066)***	0.3357 (0.0064)***	0.1139 (0.0203)***
		β_k	0.3490 (0.0025)***	0.1078 (0.0035)***	0.0837 (0.0034)***	0.1589 (0.0369)***
		NOO	103617	84941	84941	103617
Medical and Pharmaceutical Product	27	β_l	0.5416 (0.0077)***	0.3980 (0.0131)***	0.3792 (0.0129)***	0.1306 (0.0263)***
		β_k	0.3723 (0.0051)***	0.1026 (0.0065)***	0.0796 (0.0065)***	0.1650 (0.0244)***
		NOO	28635	23768	23768	28635

Note: * 10% significant, ** 5% significant, *** 1% significant.

Table 3.5: Estimation Results of Production Function (Continued)

Industry	ID	Coef	OLS	Firm Fixed Effect	Firm+ Time Fixed Effect	LP
Chemical Fiber Production	28	β_l	0.5348 (0.0132)***	0.4777 (0.0271)***	0.4394 (0.0267)***	0.1441 (0.0200)***
		β_k	0.2963 (0.0086)***	0.1195 (0.0147)***	0.0988 (0.0144)***	0.1750 (0.0548)***
		NOO	6728	5481	5481	6728
Rubber Products	29	β_l	0.4851 (0.0085)***	0.4110 (0.0145)***	0.3957 (0.0142)***	0.0996 (0.0193)***
		β_k	0.2982 (0.0060)***	0.1046 (0.0081)***	0.0812 (0.0079)***	0.1581 (0.0331)***
		NOO	17017	13962	13962	17017
Plastic Products	30	β_l	0.4638 (0.0045)***	0.3576 (0.0079)***	0.3369 (0.0077)***	0.1665 (0.0236)***
		β_k	0.3047 (0.0029)***	0.1022 (0.0046)***	0.0832 (0.0045)***	0.1602 (0.0349)***
		NOO	65103	52798	52798	65103
Nonmetal Mineral Products	31	β_l	0.3853 (0.0035)***	0.3327 (0.0056)***	0.3305 (0.0055)***	0.1244 (0.0182)***
		β_k	0.3121 (0.0022)***	0.0847 (0.0030)***	0.0753 (0.0029)***	0.1310 (0.0224)***
		NOO	121043	99454	99454	121043
Smelting and Pressing of Ferrous Merals	32	β_l	0.5494 (0.0070)***	0.4991 (0.0122)***	0.4715 (0.0118)***	0.1726 (0.0189)***
		β_k	0.3080 (0.0047)***	0.1175 (0.0063)***	0.0867 (0.0061)***	0.1599 (0.0993)
		NOO	32756	26333	26333	32756
Smelting and Pressing of Nonferrous Merals	33	β_l	0.4575 (0.0087)***	0.4447 (0.0145)***	0.4086 (0.0140)***	0.1718 (0.0227)***
		β_k	0.2883 (0.0056)***	0.1096 (0.0073)***	0.0747 (0.0071)***	0.1850 (0.0736)**
		NOO	25175	20421	20421	25175
Metal Products	34	β_l	0.4698 (0.0043)***	0.3553 (0.0073)***	0.3309 (0.0072)***	0.1520 (0.0208)***
		β_k	0.3027 (0.0028)***	0.1123 (0.0039)***	0.0882 (0.0039)***	0.1471 (0.0263)***
		NOO	74532	60466	60466	74532
Ordinary Machinery	35	β_l	0.4571 (0.0038)***	0.3862 (0.0062)***	0.3601 (0.0060)***	0.1278 (0.0188)***
		β_k	0.2955 (0.0026)***	0.1070 (0.0032)***	0.0771 (0.0031)***	0.1407 (0.0237)***
		NOO	108524	88584	88584	108524
Special Purpose Equipment	36	β_l	0.4414 (0.0058)***	0.3768 (0.0088)***	0.3605 (0.0087)***	0.0814 (0.0230)***
		β_k	0.2911 (0.0040)***	0.1109 (0.0047)***	0.0860 (0.0047)***	0.1629 (0.0249)***
		NOO	55816	45475	45475	55816
Transport Equipment	37	β_l	0.5648 (0.0051)***	0.4261 (0.0082)***	0.4062 (0.0081)***	0.1523 (0.0217)***
		β_k	0.3328 (0.0034)***	0.1094 (0.0045)***	0.0850 (0.0045)***	0.1205 (0.0372)***
		NOO	61451	50316	50316	61451
Electric Equipment and Machinery	39	β_l	0.5032 (0.0041)***	0.4128 (0.0069)***	0.3892 (0.0068)***	0.1376 (0.0216)***
		β_k	0.3240 (0.0028)***	0.1183 (0.0037)***	0.0941 (0.0037)***	0.1514 (0.0260)***
		NOO	84276	69021	69021	84276

Note: * 10% significant, ** 5% significant, *** 1% significant.

Table 3.5: Estimation Results of Production Function (Continued)

Industry	ID	Coef	OLS	Firm Fixed Effect	Firm+ Time Fixed Effect	LP
Electronic and Telecommunications	40	β_l	0.5172 (0.0058)***	0.4645 (0.0101)***	0.4419 (0.0100)***	0.1596 (0.0197)***
		β_k	0.3485 (0.0039)***	0.1162 (0.0062)***	0.0946 (0.0062)***	0.1024 (0.0564)*
		NOO	43467	35426	35426	43467
Instruments, Meters, Cultural and Clerical Machinery	41	β_l	0.4554 (0.0089)***	0.3887 (0.0150)***	0.3769 (0.0149)***	0.1384 (0.0229)***
		β_k	0.2724 (0.0059)***	0.0968 (0.0082)***	0.0802 (0.0082)***	0.1441 (0.0363)***
		NOO	18817	15405	15405	18817
Handicraft and Other Manufacturing	42	β_l	0.4864 (0.0057)***	0.3003 (0.0090)***	0.2956 (0.0089)***	0.2091 (0.0188)***
		β_k	0.2212 (0.0038)***	0.0750 (0.0051)***	0.0595 (0.0051)***	0.0932 (0.0224)***
		NOO	29734	24217	24217	29734
Waste Resources and Material Recycling	43	β_l	0.7816 (0.1137)***	1.0042 (0.1783)***	0.7601 (0.1820)***	0.1468 (0.0727)**
		β_k	0.2457 (0.0531)***	0.2467 (0.0949)***	0.1425 (0.0950)***	0.2457 (0.0487)***
		NOO	1128	848	848	1128
Production and Supply of Power, Steam and HotWater	44	β_l	0.5117 (0.0058)***	0.2086 (0.0123)***	0.2062 (0.0120)***	0.1849 (0.0197)***
		β_k	0.5960 (0.0036)***	0.1042 (0.0058)***	0.0894 (0.0058)***	0.1897 (0.0791)**
		NOO	33951	28894	28894	33951
Production and Supply of Gas	45	β_l	0.2103 (0.0289)***	0.2396 (0.0590)***	0.1957 (0.0565)***	0.0738 (0.0236)***
		β_k	0.4170 (0.0207)***	0.1473 (0.0266)***	0.1139 (0.0256)***	0.2212 (0.0587)***
		NOO	2079	1711	1711	2079
Production and Supply of Tap Water	46	β_l	0.5503 (0.0079)***	0.2238 (0.0208)***	0.1790 (0.0205)***	0.2541 (0.0218)***
		β_k	0.4921 (0.0045)***	0.0332 (0.0074)***	0.0160 (0.0073)***	0.1169 (0.0134)***
		NOO	18162	15820	15820	18162

Note: * 10% significant, ** 5% significant, *** 1% significant.

Table 3.6: Productivity Growth Over Time

Industry	ID	Period	Productivity Growth Rate
Coal Mining and Processing	6	1997-1998	-1.11%
		1998-1999	-0.65%
		1999-2000	-1.97%
		2000-2001	9.79%
		2001-2002	-2.32%
		2002-2003	16.21%
		2003-2004	-0.43%
		2004-2005	-4.34%
		2005-2006	19.92%
Petroleum and Natural Gas Extraction	7	1997-1998	-0.66%
		1998-1999	113.10%
		1999-2000	-19.99%
		2000-2001	-7.80%
		2001-2002	2.88%
		2002-2003	37.42%
		2003-2004	7.37%
		2004-2005	-10.70%
		2005-2006	-14.87%
Ferrous Metal Mining and Dressing	8	1997-1998	9.09%
		1998-1999	-4.54%
		1999-2000	58.75%
		2000-2001	-39.28%
		2001-2002	0.06%
		2002-2003	58.32%
		2003-2004	-2.67%
		2004-2005	-9.32%
		2005-2006	10.42%
Nonferrous Metal Mining and Dressing	9	1997-1998	-68.24%
		1998-1999	-3.53%
		1999-2000	42.75%
		2000-2001	-35.31%
		2001-2002	5.26%
		2002-2003	43.02%
		2003-2004	72.05%
		2004-2005	-5.88%
		2005-2006	11.54%
Nonmetal Mining and Dressing	10	1997-1998	83.71%
		1998-1999	-63.79%
		1999-2000	-1.56%
		2000-2001	-3.40%
		2001-2002	-7.02%
		2002-2003	7.43%
		2003-2004	39.46%
		2004-2005	-15.83%
		2005-2006	13.07%
Other Minerals Mining and Dressing	11	1997-1998	-53.82%
		1998-1999	38.63%
		1999-2000	-22.20%
		2000-2001	20.09%
		2001-2002	169.28%
		2002-2003	-47.86%
		2003-2004	-2.72%
		2004-2005	1.96%
		2005-2006	-0.63%

Table 3.6: Productivity Growth Over Time (Continued)

Industry	ID	Period	Productivity Growth Rate
Food Processing	13	1997-1998	-31.20%
		1998-1999	-7.27%
		1999-2000	0.48%
		2000-2001	19.59%
		2001-2002	-24.16%
		2002-2003	-2.36%
		2003-2004	19.06%
		2004-2005	7.15%
		2005-2006	-2.99%
Food Production	14	1997-1998	2.22%
		1998-1999	-3.53%
		1999-2000	-10.33%
		2000-2001	12.03%
		2001-2002	0.91%
		2002-2003	33.58%
		2003-2004	-17.70%
		2004-2005	6.49%
		2005-2006	-6.85%
Beverage Production	15	1997-1998	25.23%
		1998-1999	-11.40%
		1999-2000	2.70%
		2000-2001	-2.24%
		2001-2002	-0.96%
		2002-2003	26.42%
		2003-2004	-5.76%
		2004-2005	-3.68%
		2005-2006	7.33%
Tobacco Processing	16	1997-1998	12.41%
		1998-1999	-14.23%
		1999-2000	-1.33%
		2000-2001	9.13%
		2001-2002	4.07%
		2002-2003	4.49%
		2003-2004	-8.67%
		2004-2005	10.99%
		2005-2006	40.56%
Textile Industry	17	1997-1998	6.40%
		1998-1999	-11.93%
		1999-2000	2.47%
		2000-2001	6.83%
		2001-2002	0.72%
		2002-2003	8.61%
		2003-2004	17.26%
		2004-2005	5.42%
		2005-2006	13.84%
Textile Clothing Shoes Hats Production	18	1997-1998	-42.09%
		1998-1999	7.11%
		1999-2000	6.50%
		2000-2001	-8.58%
		2001-2002	2.41%
		2002-2003	27.77%
		2003-2004	-8.27%
		2004-2005	19.64%
		2005-2006	-14.51%

Table 3.6: Productivity Growth Over Time (Continued)

Industry	ID	Period	Productivity Growth Rate
Leather Furs Down and Related Products	19	1997-1998	-39.68%
		1998-1999	7.78%
		1999-2000	6.70%
		2000-2001	-12.10%
		2001-2002	3.95%
		2002-2003	3.05%
		2003-2004	3.13%
		2004-2005	16.21%
		2005-2006	9.33%
Logging and Transport of Timber and Banboo	20	1997-1998	2.21%
		1998-1999	10.32%
		1999-2000	2.67%
		2000-2001	4.57%
		2001-2002	-12.96%
		2002-2003	7.89%
		2003-2004	10.30%
		2004-2005	9.46%
		2005-2006	24.77%
Furniture Manufacturing	21	1997-1998	-48.51%
		1998-1999	8.03%
		1999-2000	21.06%
		2000-2001	8.71%
		2001-2002	-41.21%
		2002-2003	84.65%
		2003-2004	-36.98%
		2004-2005	-1.39%
		2005-2006	16.32%
Papermaking and Paper Product	22	1997-1998	-14.41%
		1998-1999	-10.07%
		1999-2000	-2.64%
		2000-2001	4.42%
		2001-2002	-2.13%
		2002-2003	4.67%
		2003-2004	30.75%
		2004-2005	-20.66%
		2005-2006	14.04%
Pringting and Record Medium Reproduction	23	1997-1998	-9.85%
		1998-1999	-5.45%
		1999-2000	10.11%
		2000-2001	-1.09%
		2001-2002	-6.11%
		2002-2003	13.49%
		2003-2004	-7.23%
		2004-2005	9.39%
		2005-2006	1.83%
Cultural Educational and Sports Goods	24	1997-1998	-26.19%
		1998-1999	2.23%
		1999-2000	15.78%
		2000-2001	-10.70%
		2001-2002	-0.07%
		2002-2003	14.54%
		2003-2004	-10.19%
		2004-2005	0.67%
		2005-2006	4.91%

Table 3.6: Productivity Growth Over Time (Continued)

Industry	ID	Period	Productivity Growth Rate
Petroleum Refining and Coking	25	1997-1998	1.69%
		1998-1999	-8.51%
		1999-2000	-6.63%
		2000-2001	30.99%
		2001-2002	-5.98%
		2002-2003	8.08%
		2003-2004	7.97%
		2004-2005	6.23%
		2005-2006	12.32%
Raw Chemical Materials and Chemical Products	26	1997-1998	-54.59%
		1998-1999	2.05%
		1999-2000	6.82%
		2000-2001	-7.13%
		2001-2002	8.30%
		2002-2003	28.24%
		2003-2004	-16.28%
		2004-2005	1.85%
		2005-2006	4.31%
Medical and Phamaceuti-cal Products	27	1997-1998	17.47%
		1998-1999	0.10%
		1999-2000	2.77%
		2000-2001	56.44%
		2001-2002	-44.31%
		2002-2003	19.67%
		2003-2004	-12.68%
		2004-2005	-7.94%
		2005-2006	-0.59%
Chemical Fiber Production	28	1997-1998	-1.88%
		1998-1999	-14.06%
		1999-2000	-0.85%
		2000-2001	16.13%
		2001-2002	-12.24%
		2002-2003	-1.32%
		2003-2004	-0.45%
		2004-2005	1.78%
		2005-2006	19.89%
Rubber Products	29	1997-1998	0.77%
		1998-1999	-2.54%
		1999-2000	6.30%
		2000-2001	-4.61%
		2001-2002	-3.17%
		2002-2003	31.89%
		2003-2004	-30.38%
		2004-2005	0.59%
		2005-2006	2.90%
Plastic Products	30	1997-1998	-13.02%
		1998-1999	9.35%
		1999-2000	4.86%
		2000-2001	-0.77%
		2001-2002	3.71%
		2002-2003	-2.19%
		2003-2004	-1.57%
		2004-2005	17.62%
		2005-2006	103.19%

Table 3.6: Productivity Growth Over Time (Continued)

Industry	ID	Period	Productivity Growth Rate
Nonmetal Mineral Products	31	1997-1998	-6.76%
		1998-1999	26.29%
		1999-2000	81.45%
		2000-2001	-52.56%
		2001-2002	5.26%
		2002-2003	3.59%
		2003-2004	6.47%
		2004-2005	11.03%
		2005-2006	8.16%
Smelting and Pressing of Ferrous Merals	32	1997-1998	11.28%
		1998-1999	2.32%
		1999-2000	6.03%
		2000-2001	3.02%
		2001-2002	18.16%
		2002-2003	25.88%
		2003-2004	-9.52%
		2004-2005	0.34%
		2005-2006	-4.46%
Smelting and Pressing of Nonferrous Merals	33	1997-1998	262.06%
		1998-1999	-64.06%
		1999-2000	15267.81%
		2000-2001	271.51%
		2001-2002	-99.85%
		2002-2003	7.17%
		2003-2004	5.42%
		2004-2005	2.34%
		2005-2006	-5.08%
Petroleum and Natural Gas Extraction	34	1997-1998	-0.21%
		1998-1999	35.25%
		1999-2000	-9.55%
		2000-2001	1.94%
		2001-2002	0.35%
		2002-2003	-1.10%
		2003-2004	50.36%
		2004-2005	-36.42%
		2005-2006	12.32%
Ordinary Machinery	35	1997-1998	-2.71%
		1998-1999	0.62%
		1999-2000	-0.38%
		2000-2001	-1.30%
		2001-2002	1.88%
		2002-2003	5.03%
		2003-2004	3.29%
		2004-2005	-1.58%
		2005-2006	8.69%
Special Purpose Equipment	36	1997-1998	-8.63%
		1998-1999	71.80%
		1999-2000	-38.41%
		2000-2001	0.73%
		2001-2002	-4.40%
		2002-2003	10.67%
		2003-2004	9.12%
		2004-2005	6.56%
		2005-2006	-3.96%

Table 3.6: Productivity Growth Over Time (Continued)

Industry	ID	Period	Productivity Growth Rate
Transport Equipment	37	1997-1998	15.70%
		1998-1999	-11.57%
		1999-2000	1.16%
		2000-2001	11.41%
		2001-2002	5.00%
		2002-2003	-4.51%
		2003-2004	16.71%
		2004-2005	-3.39%
		2005-2006	-4.48%
Electric Equipment and Machinery	39	1997-1998	-27.89%
		1998-1999	12.41%
		1999-2000	-3.99%
		2000-2001	-1.04%
		2001-2002	-5.98%
		2002-2003	15.21%
		2003-2004	-2.37%
		2004-2005	-13.77%
		2005-2006	-0.55%
Electronic and Telecommunications	40	1997-1998	-9.83%
		1998-1999	12.98%
		1999-2000	-5.33%
		2000-2001	19.94%
		2001-2002	-2.43%
		2002-2003	13.18%
		2003-2004	1.41%
		2004-2005	2.71%
		2005-2006	-20.98%
Instruments Meters Cultural and Clerical Machinery	41	1997-1998	-12.10%
		1998-1999	60.92%
		1999-2000	-28.30%
		2000-2001	1.26%
		2001-2002	-10.18%
		2002-2003	10.43%
		2003-2004	6.85%
		2004-2005	-2.75%
		2005-2006	0.13%
Handicraft and Other Manufacturing	42	1997-1998	-10.18%
		1998-1999	5.58%
		1999-2000	3.44%
		2000-2001	-11.45%
		2001-2002	-5.05%
		2002-2003	15.25%
		2003-2004	12.95%
		2004-2005	-12.13%
		2005-2006	10.14%
Waste Resources and Material Recycling	43	1997-1998	-15.00%
		1998-1999	-1.83%
		1999-2000	0.27%
		2000-2001	2.65%
		2001-2002	-3.37%
		2002-2003	19.82%
		2003-2004	31.15%
		2004-2005	-22.26%
		2005-2006	-0.58%

Table 3.6: Productivity Growth Over Time (Continued)

Industry	ID	Period	Productivity Growth Rate
Production and Supply of Power Steam and HotWater	44	1997-1998	-10.68%
		1998-1999	-25.01%
		1999-2000	11.23%
		2000-2001	3.95%
		2001-2002	5.45%
		2002-2003	-28.87%
		2003-2004	29.92%
		2004-2005	2622.56%
		2005-2006	173.06%
Production and Supply of Gas	45	1997-1998	30.87%
		1998-1999	-33.00%
		1999-2000	58.19%
		2000-2001	-34.95%
		2001-2002	22.72%
		2002-2003	392.06%
		2003-2004	-72.33%
		2004-2005	-8.05%
		2005-2006	10.27%
Production and Supply of Tap Water	46	1997-1998	-7.34%
		1998-1999	1.51%
		1999-2000	6.13%
		2000-2001	-2.88%
		2001-2002	2.30%
		2002-2003	7.75%
		2003-2004	0.96%
		2004-2005	-1.64%
		2005-2006	19.53%

Figure 3·2: Growth of Weighted Average Productivities

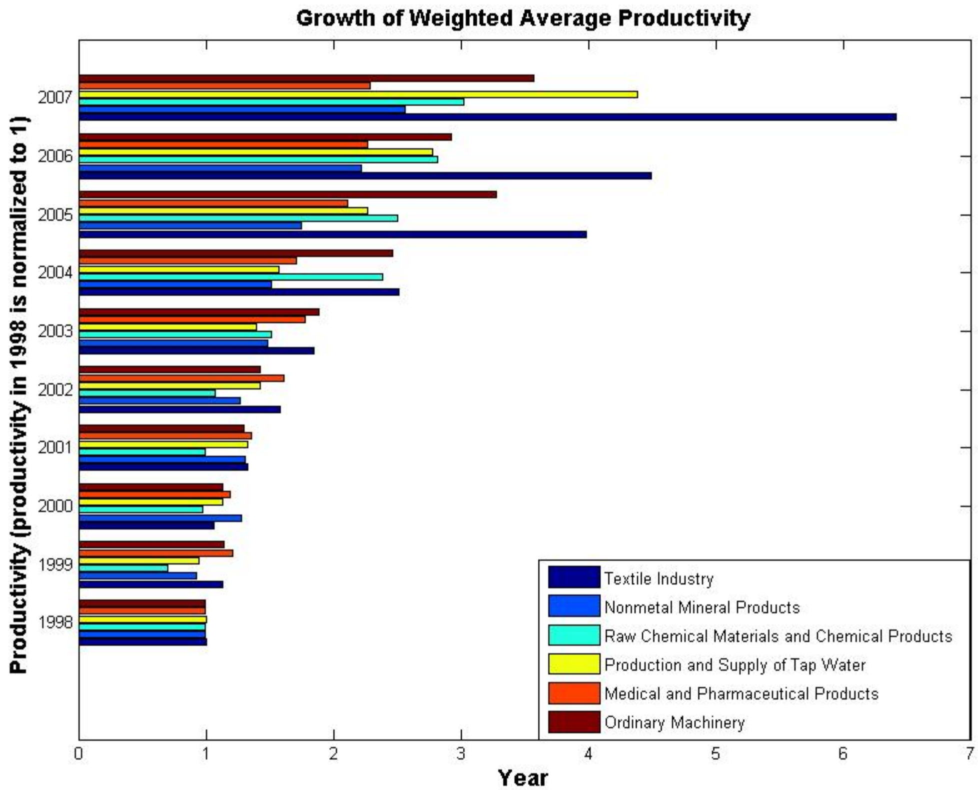


Figure 3·3: Growth of Unweighted Average Productivities

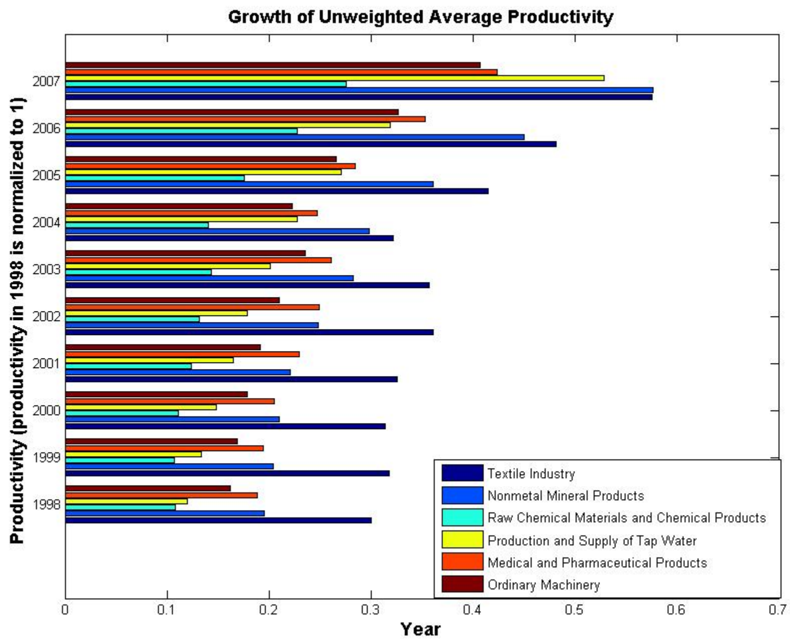


Figure 3·4: Growth of covariance between market share and productivity without market size adjustment

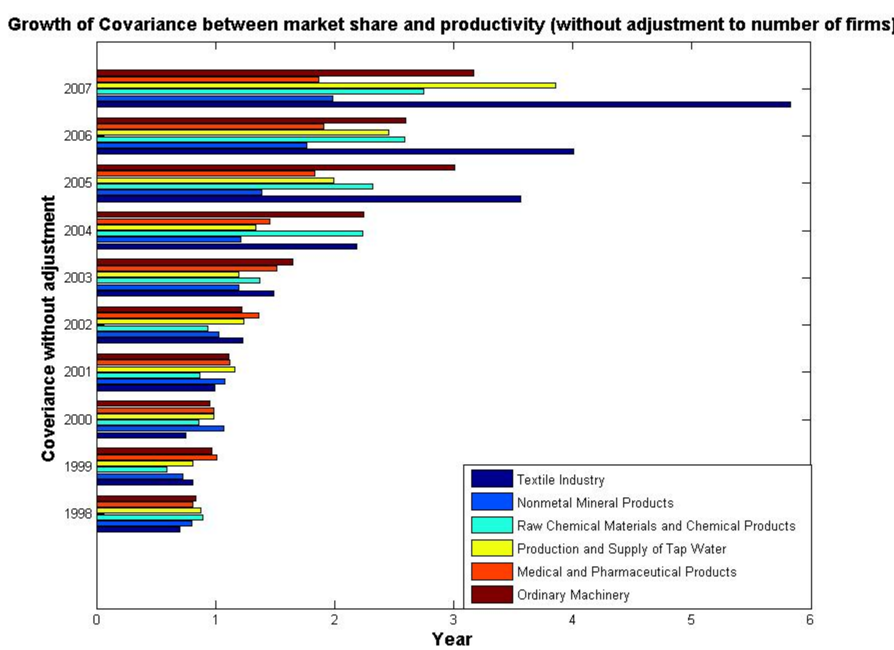


Figure 3·5: Growth of correlation coefficient between market share and productivity

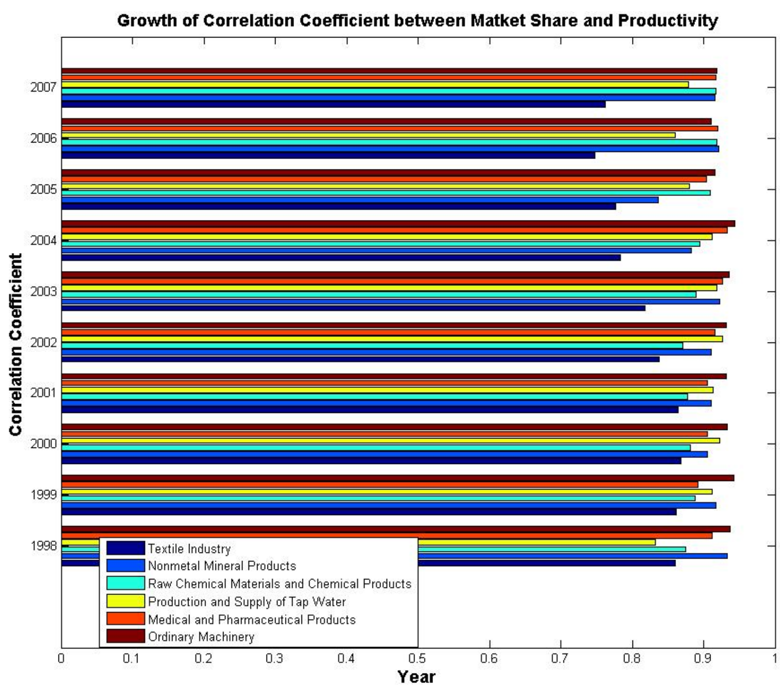


Table 3.7: Effects of Reform on Productivity

Industry	ID	Model	Coef on Priv
Coal Mining and Processing	6	Model 1	-201.32 (210.82)
		Model 2	-298.27 (207.82)
		Model 3	-262.72 (206.75)
		Model 4	-245.70 (236.34)
Ferrous Metal Mining and Dressing	8	Model 1	71.71 (68.49)
		Model 2	65.49 (66.52)
		Model 3	7.62 (56.51)
		Model 4	1.32 (68.18)
Nonferrous Metal Mining and Dressing	9	Model 1	-435.80 (600.62)
		Model 2	-475.72 (561.76)
		Model 3	-539.39 (561.72)
		Model 4	-723.57 (726.49)
Nonmetal Mining and Dressing	10	Model 1	103.77 (100.08)
		Model 2	108.78 (99.23)
		Model 3	128.45 (97.39)
		Model 4	133.06 (118.28)
Food Processing	13	Model 1	70.44 (50.91)
		Model 2	85.49 (50.65)*
		Model 3	67.94 (50.25)
		Model 4	52.57 (60.09)
Food Production	14	Model 1	192.51 (80.81)**
		Model 2	223.00 (79.67)***
		Model 3	215.94 (78.66)***
		Model 4	231.89 (92.21)**
Beverage Production	15	Model 1	-104.07 (191.11)
		Model 2	25.86 (188.56)
		Model 3	15.37 (187.43)
		Model 4	31.78 (234.74)

Table 3.7: Effects of Reform on Productivity (Continued)

Industry	ID	Model	Coef on Priv
Tobacco Processing	16	Model 1	-1345.71 (2809.94)
		Model 2	-1862.97 (2729.63)
		Model 3	-1498.38 (2515.02)
		Model 4	-758.69 (3076.27)
Textile Industry	17	Model 1	152.30 (71.06)**
		Model 2	193.19 (70.52)***
		Model 3	183.93 (69.88)***
		Model 4	207.66 (87.08)**
Textile Clothing, Shoes, Hats Production	18	Model 1	209.59 (54.04)***
		Model 2	224.44 (53.12)***
		Model 3	197.92 (52.45)***
		Model 4	236.89 (63.17)***
Logging and Transport of Timber and Banboo	20	Model 1	8.00 (59.33)
		Model 2	-2.81 (57.23)
		Model 3	-15.13 (57.33)
		Model 4	-29.25 (68.86)
Furniture Manufacturing	21	Model 1	-69.52 (77.72)
		Model 2	-62.16 (73.44)
		Model 3	-57.89 (73.15)
		Model 4	-71.58 (91.59)
Papermaking and Paper Product	22	Model 1	-230.68 (156.56)
		Model 2	-151.69 (154.92)
		Model 3	-145.29 (154.46)
		Model 4	-236.71 (191.57)
Pringting and Record Medium Reproduction	23	Model 1	88.15 (40.26)**
		Model 2	108.22 (39.88)*
		Model 3	112.69 (39.86)*
		Model 4	56.82 (44.22)

Table 3.7: Effects of Reform on Productivity (Continued)

Industry	ID	Model	Coef on Priv
Petroleum Refining and Coking	25	Model 1	228.61 (793.80)
		Model 2	48.56 (776.97)
		Model 3	-238.76 (747.17)
		Model 4	-174.92 (872.46)
Raw Chemical Materials and Chemical Products	26	Model 1	62.70 (70.52)
		Model 2	129.72 (69.50)*
		Model 3	106.14 (68.69)
		Model 4	118.85 (83.78)
Medical and Phamaceutical Products	27	Model 1	-49.68 (96.22)
		Model 2	-17.68 (95.28)
		Model 3	-6.15 (94.84)
		Model 4	-77.40 (110.58)
Rubber Products	29	Model 1	226.57 (448.36)
		Model 2	348.55 (450.40)
		Model 3	236.24 (436.16)
		Model 4	512.29 (480.65)
Plastic Products	30	Model 1	14.85 (89.64)
		Model 2	27.56 (89.07)
		Model 3	23.79 (89.02)
		Model 4	14.58 (125.22)
Nonmetal Mineral Products	31	Model 1	98.62 (50.79)*
		Model 2	138.69 (50.21)***
		Model 3	126.70 (49.85)**
		Model 4	128.62 (59.47)**
Smelting and Pressing of Ferrous Merals	32	Model 1	-481.96 (590.45)
		Model 2	-475.82 (584.96)
		Model 3	-515.49 (582.78)
		Model 4	-396.26 (730.40)

Table 3.7: Effects of Reform on Productivity (Continued)

Industry	ID	Model	Coef on Priv
Smelting and Pressing of Nonferrous Merals	33	Model 1	-297.79 (408.77)
		Model 2	-128.98 (377.72)
		Model 3	-201.12 (375.03)
		Model 4	-409.86 (494.08)
Metal Products	34	Model 1	-159.75 (93.78)*
		Model 2	-143.37 (92.37)
		Model 3	-136.74 (91.73)
		Model 4	-181.37 (108.82)*
Ordinary Machinery	35	Model 1	97.30 (84.81)
		Model 2	103.97 (83.92)
		Model 3	111.49 (83.49)
		Model 4	101.15 (99.17)
Special Purpose Equipment	36	Model 1	163.10 (149.14)
		Model 2	166.82 (146.12)
		Model 3	173.68 (145.86)
		Model 4	125.32 (174.00)
Transport Equipment	37	Model 1	79.54 (213.83)
		Model 2	169.57 (209.25)
		Model 3	190.04 (208.87)
		Model 4	-28.58 (255.22)
Electric Equipment and Machinery	39	Model 1	42.01 (186.24)
		Model 2	82.09 (185.79)
		Model 3	32.03 (185.43)
		Model 4	-111.17 (228.28)
Electronic and Telecommunications	40	Model 1	-691.12 (550.06)
		Model 2	-743.32 (547.54)
		Model 3	-475.30 (537.22)
		Model 4	-625.60 (652.27)

Table 3.7: Effects of Reform on Productivity (Continued)

Industry	ID	Model	Coef on Priv
Instruments, Meters, Cultural and Clerical Machinery	41	Model 1	115.49 (112.65)
		Model 2	166.38 (108.56)
		Model 3	167.86 (107.08)
		Model 4	90.76 (126.39)
Handicraft and Other Manufacturing	42	Model 1	327.01 (209.10)
		Model 2	523.22 (205.35)
		Model 3	503.01 (203.14)
		Model 4	698.93 (275.74)
Production and Supply of Power, Steam and HotWater	44	Model 1	51.99 (117.75)
		Model 2	48.56 (117.84)
		Model 3	60.92 (117.70)
		Model 4	53.16 (128.44)
Production and Supply of Gas	45	Model 1	207.82 (361.20)
		Model 2	158.58 (357.78)
		Model 3	57.37 (358.71)
		Model 4	-54.05 (412.14)
Production and Supply of Tap Water	46	Model 1	128.74 (26.33)***
		Model 2	120.74 (26.25)***
		Model 3	126.81 (25.96)***
		Model 4	128.42 (25.79)***

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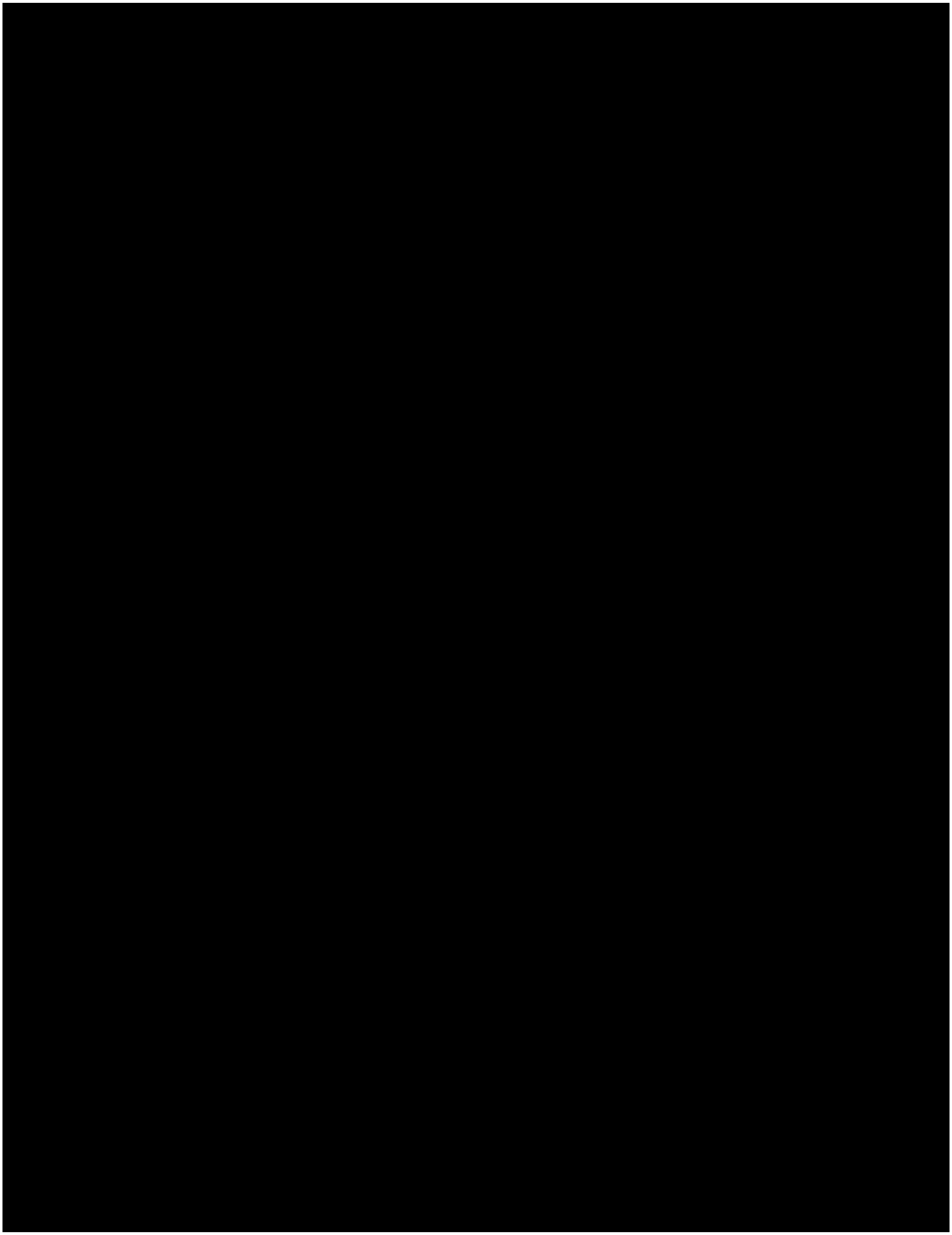

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